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ENVIRONMENTAL PROTECTION AGENCY

OFFICE OF WATER SUPPLY

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Page

INTRODUCTION 1

KEY TO WELL STANDARDS 6

GENERAL PREAMBLE 9

Section 1. **GENERAL CONDITIONS** 11

Article

1. **Definition of Terms** 11
2. Award, Execution of Documents, Delivery of Bonds, etc. 12
3. **Progress and Submission Schedules; Preconstruction Conference; Time for Starting the Work** 13
4. Correlation, Interpretation and Intent of Contract Documents 14
5. **Ownership and Copies of Documents; Record Documents** 14
6. **Work by Others** 15
7. **Subcontracts** 16
8. **Materials, Equipment and Labor; Substitute Material or Equipment** 17
9. **Patent Fees and Royalties** 18
10. **Permits, Laws, Taxes and Regulations** 18
11. Availability of Lands; Physical and Subsurface Conditions; Reference Points 18
12. Use of Premises 19
13. OWNER's Status During Construction 20
14. **PROJECT REPRESENTATIVE'S Interpretation and Decisions** 21
15. Shop Drawings and Samples 22
16. Tests and Inspections 23
17. **CONTRACTOR'S Supervision and Superintendance** 23
18. Safety and Protection; **Emergencies** 24
19. Access to the Work; **Uncovering Finished Work** 25
20. Changes in the Work 26
21. Change of Contract Price 27
22. Cash Allowances 28
23. Change of the Contract Time 28
24. Neglected Work 29
25. Warranty and Guarantee; Correction, Removal or Acceptance of Defective Work 29
26. Application for Progress Payments 31
27. Approval of Payments 31
28. Substantial Completion 32
29. Partial Utilization 33
30. Final Payment 34
31. Waivers of Claims and Continuing Obligations 35

Page
32. Indemnification 35
33. Contract Bonds 36
34. CONTRACTOR'S Liability Insurance 36
35. OWNER'S Liability Insurance 37
36. Property Insurance 37
37. Cleaning up 38
38. OWNER'S Right to Stop or Suspend Work 38
39. OWNER'S Right to Terminate 39
40. CONTRACTOR'S Right to Stop Work or Terminate 40
41. Arbitration 40
42. Miscellaneous 41

Section 3 SPECIAL CONDITIONS 43

Article

43. General 43
44. Glossary of Technical Terms 43

Section 4. TECHNICAL STANDARDS 49

Article

45. Test Holes and Samples 49

HOLE LOCATION AND PURPOSE

45.100-000-000. Hole Location and Purpose 51

DRILLING METHODS

45.010-000-000. Contractor's Choice 51
45.020-000-000. Driven Well Point Method 51
45.030-000-000. Jetting or Hydraulicing Method 51
45.040-000-000. Reverse Hydraulic Rotary Method 51
45.050-000-000. Air Rotary Method 51
45.060-000-000. Rotary Method 51
45.070-000-000. Combined Driving and Drilling Method 51
45.080-000-000. Cable Tool Method 52

DRILLER'S LOGS AND REPORTS

45.001-000-000. Driller's Log 52
45.002-000-000. Daily Driller's Report 53
45.003-000-000. Penetration Rate Log 54
45.040-000-000. Stratigraphic Log 55

GEOPHYSICAL/MECHANICAL LOGS

45.000-100-000. Geophysical/Mechanical Logs 56

FORMATION SAMPLING METHODS

45.000-010-000. Contractor's Choice 56
45.000-020-000. Return Flow Method (Continuous) 56
45.000-030-000. Return Flow Method (Circulated) 58
45.000-040-000. Auger Method 59
45.000-050-000. Bailer Method 59
45.000-060-000. Core Barrel Method 59
45.000-070-000. Piston Tube Method 59

Page
45.000-080-000. Split Spoon Method 59
45.000-090-000. Side Wall Core Method 59

FORMATION SAMPLING INTERVAL

45.000-001-000. Sampling by Formation Interval 60
45.000-002-000. Sampling by Measured Intervals 60
45.000-003-000. Sampling by Measured and Formation Intervals 60

WATER (AQUIFER) SAMPLING

45.000-000-100. Water Sampling 60

FORMATION SAMPLE SIZE, HANDLING AND IDENTIFICATION

45.000-000-010. Size of Sample: Containers, Identification, Storage and Transfer 61

METHOD OF PAYMENT FOR TEST HOLES AND SAMPLES

45.000-000-001. Method of Payment
Option A (Lump Sum) 61
Option B (Time and Materials) 62
Option C (Unit Price) 63
Article
46. Well Construction 63

METHODS OF CONSTRUCTION

46.100-000-000. Methods of Construction 66

DRILLING FLUID CONTROL PROGRAM

46.010-000-000. Production Zone Protection 67

DRILLER'S LOG AND REPORTS

46.001-000-000. Logs 68

TEMPORARY CAPPING

46.000-100-000. Temporary Capping 68

METHOD OF PAYMENT OF WELL CONSTRUCTION

46.000-010-000. Method of Payment
Option A (Lump Sum) 68
Option B (Time and Materials) 68
Option C (Unit Price) 69
Article
47. Well Casing Selection and Installation 69

CASING SELECTION

47.100-000-000. Well Casing Selection 74

METHODS OF INSTALLATION

47.010-000-000. Driven (Well Point) 76
47.020-000-000. Jacking 76
47.030-000-000. Driven (Drive Shoe) 76
47.040-000-000. Lowering 76
47.050-000-000. Floating 76

Page

METHOD OF JOINING

47.001-000-000. Contractor's Choice 77

SANITARY PROTECTION OF WELL

47.000-100-000. Termination at Top of Well 77

CASING SEATING

47.000-010-000. Unconsolidated Formations 78
47.000-020-000. Consolidated Formations 78

PRESSURE TESTING OF SEATING

47.000-001-000. Pressure Testing of Seating 78

METHOD OF PAYMENT FOR CASING AND INSTALLATION

47.000-000-100. Method of Payment
Option A (Lump Sum) 78
Option B (Time and Materials) 78
Option C (Unit Price) 78
Article
48. Well Grouting 79

GROUTING MATERIALS TO BE USED

48.100-000-000. Concrete Grout 81
48.200-000-000. Sand Cement Grout 81
48.300-000-000. Neat Cement Grout 81

METHODS OF INSTALLATION OF GROUT

48.010-000-000. Bailer Dumping 81
48.020-000-000. Gravity Filling Without Tremie Method 82
48.030-000-000. Tremie Method 82
48.040-000-000. Positive Placement—Exterior Method 82
48.050-000-000. Positive Placement—Exterior Method—Two Plug 83
48.060-000-000. Positive Placement—Interior Method—Upper Plug 83
48.070-000-000. Positive Placement—Interior Method-Capped Casing 83
48.080-000-000. Continuous Injection Method 84
48.090-000-000. Grout Displacement Method 84

LOCATION OF GROUT

48.001-000-000. Surface Formation Seal 85
48.002-000-000. Bottom Seal Grouting 85
48.003-000-000. Selected Interval Grouting 85
48.004-000-000. Continuous Grouting 85

CENTRALIZERS

48.000-100-000. Contractor's Choice 86
48.000-200-000. Centralizers at Bottom of Hole 87
48.000-300-000. Centralizers at Bottom of Hole and Other Critical Grouting Points 87
48.000-400-000. Centralizers at 25 Foot Intervals 87

Page

GEOPHYSICAL LOGGING FOR CEMENT BOND

48.000-010-000. Acoustic-Sonic Cement Bond Log 87

PRESSURE TESTING OF GROUT SEAL

48.000-001-000. Pressure Testing of Grout Seal 87

METHOD OF PAYMENT FOR GROUTING

48.000-100-100. Method of Payment
Option A (Lump Sum) 87
Option B (Time and Materials) 87
Option C (Unit Price) 87

Article
49. Well Screen and Perforations 88

FILTER TYPE SCREEN

49.100-000-000. Filter Type Selection 90

SCREEN TYPE SELECTION

49.010-000-000. Contractor's Choice 90
49.020-000-000. Perforated Pipe 90
49.030-000-000. Punched (With Material Removed) and Slotted Pipe 91
49.040-000-000. Reinforced Wire Wrapped Punched Pipe 91
49.050-000-000. Artificial Filter Screen (Precast) 91
49.060-000-000. Louvred Pipe 91
49.070-000-000. Continuous Slot Wire Wound Screen 91

SCREEN APERATURE SIZE

49.001-000-000. Contractor's Choice 91
49.0002-000-000. Aperature Size Selection Criteria 91

SCREEN LENGTH

49.000-100-000. Contractor's Choice 92
49.000-200-000. Screen Length Selection Criteria 92

METHOD OF SCREEN INSTALLATION

49.000-010-000. Contractor's Choice 93
49.000-020-000. Driven Well Point Method 93
49.000-030-000. Washing Method 93
49.000-040-000. Pull Back Method 93
49.000-050-000. Driven Through Casing Method 93
49.000-060-000. Bailed Through Casing Method 93
49.000-070-000. Bailed or Air Jetted Through Casing Method 94
49.000-080-000. Washed Through Casing Method 94
49.000-090-000. Suspend From Surface Method 94

METHOD OF JOINING SCREEN TO SCREEN

49.000-001-000. Joining 94

METHOD OF CONNECTING SCREEN TO CASING

49.000-000-100. Neoprene or Rubber Seal 94
49.000-000-200. Lead Packer 94

Page
49.000-000-300. Cement Fill in Annulus 95
49.000-000-400. Threaded, Coupled, Welded Joints 95

METHODS OF SEALING SCREEN BOTTOM

49.000-000-010. Lead Method 95
49.000-000-020. Bag Cement Method 95
49.000-000-030. Self-Closing Valve Method 95
49.000-000-040. Fabricated Plug Method 95
49.000-000-050. Welded Plate Method (Casing Material) 95
49.000-000-060. Welded Plate Method (Screen Material) 95

METHOD OF PAYMENT FOR WELL SCREENS

49.000-000-001. Method of Payment
Option A (Lump Sum) 95
Option B (Time and Materials) 95
Option C (Unit Price) 96
Article
50. Well Filter Construction (Artificial) 96

FILTER TYPE SELECTION

50.100-000-000. General Criteria 97

FILTER CONSTRUCTION STANDARDS

50.010-000-000. General 98

SELECTION OF FILTER GRAIN SIZE AND SCREEN APERTURE SIZE

50.001-000-000. Contractor's Choice 98
50.002-000-000. Selection Criteria 98

LENGTH OF ARTIFICIAL FILTER

50.000-100-000. 98
50.000-200-000. 98
50.000-300-000. 98
50.000-400-000. 98

STORAGE OF FILTER MATERIAL

50.000-010-000. Bulk Delivery—Open Storage 99
50.000-020-000. Bulk Delivery—Covered Storage 99
50.000-030-000. Bagged Delivery 99

DISINFECTION OF FILTER MATERIAL

50.000-001-000. Disinfection 99

METHOD OF INSTALLATION OF FILTER MATERIAL

50.000-000-100. Poured 99
50.000-000-200. Poured with Fluid 99
50.000-000-300. Tremie Placed 99
50.000-000-400. Tremie Placed with Fluid 99
50.000-000-500. Tremie with Fill 99
50.000-000-600. Crossover Tool 99

Page

METHOD OF PAYMENT FOR ARTIFICIAL WELL FILTER

50.000-000-010. Method of Payment
Option A (Lump Sum) 102
Option B (Time and Materials) 103
Option C (Unit Price) 103

Article
51. Well Plumbness and Alignment 103

METHODS OF TESTING

51.100-000-000. Plumbness and Alignment Test 103
51.200-000-000. Plumbness and Alignment Test .... [illegible]
51.300-000-000. Drift Indicator Survey 103

METHOD OF PAYMENT FOR WELL PLUMBNESS AND ALIGNMENT

51.010-000-000. Method of Payment
Option A (Lump Sum) 104
Option B (Time and Materials) 104
Option C (Unit Price) 104

Article
52. Well Development 104

PUMPING OR BAILING METHOD

52.100-000-000. Continuous Overpumping 105
52.200-000-000. Interrupted Overpumping 105
52.300-000-000. Surging and Bailing (Utilizing Bailer) 106
52.400-000-001. Surging and Bailing (Utilizing Surge Block) .. 107

MECHANICAL SURGING AND PUMPING METHOD

52.010-000-000. Surging and Pumping 107

HYDRAULIC JETTING METHOD

52.001-000-000. Hydraulic Jetting 107

AIR DEVELOPMENT METHOD

52.000-100-000. Single Pipe System Open to Atmosphere 107
52.000-200-000. Single Pipe System Closed to Atmosphere 107
52.000-300-000. Two Pipe System 108

DEVELOPMENT AIDS

52.000-010-000. Washing with Water 109
52.000-020-000. Washing with Chemicals 109

SAND CONTENT TESTING

52.000-001-000. Sand Content Testing 109

SAND CONTENT LIMITS

52.000-000-100. 109
52.000-000-200. 109
52.000-000-300. 109
52.000-000-400. 110
52.000-000-500. 110

Page

RECORD OF MEASUREMENT

52.000-020-010. Recording Measurements 110

METHOD OF PAYMENT FOR WELL DEVELOPMENT

52.000-000-001. Method of Payment
Option A (Lump Sum) 110
Option B (Time and Materials) 110
Option C (Unit Price) 110
Article
53. Well Testing for Performance 110

TYPES OF PUMPING TEST PERFORMED

53.100-000-000. Bailing Test Method 112
53.200-000-000. Air Blow Test Method 112
53.300-000-000. Air Lift Test Method 112
53.400-000-000. Variable Rate Method 113
53.500-000-000. Constant Rate Method 113
53.600-000-000. Step-Continuous Composite Method 114

ABORTED TESTS

53.010-000-000. Aborted Tests 115

LOCATION OF DISCHARGE

53.001-000-000. Discharge Water 115

RECORD OF PUMPING TESTS

53.000-100-000. Records 115

MEASUREMENT OF WATER LEVELS

53.000-010-000. Bailer Line Method 116
53.000-020-000. Contractor's Choice 116
53.000-030-000. Air Line Method 116
53.000-040-000. Steel Tape Method 116
53.000-050-000. Electric Sounder Method 117

COLLECTION OF WATER SAMPLES

53.000-001-000. Water Samples and Analysis 117

METHOD OF PAYMENT FOR TESTING FOR PERFORMANCE

53.000-000-100. Method of Payment
Option A (Lump Sum) 117
Option B (Time and Materials) 117
Option C (Unit Price) 117
Article
54. Well Disinfection 117

SCHEDULING DISINFECTION

54.100-000-000. 120

DISINFECTANTS

54.010-000-000. 120

Page

INTERIM DISINFECTION

[illegible] .... [illegible]

DAILY OPERATIONS DISINFECTION

[illegible] .... [illegible]

DISINFECTION PROCEDURES

[illegible] .... [illegible]

DISINFECTION OF WATER TABLE WELLS

[illegible] Dry Chlorine Compounds .... [illegible]
[illegible] Stock Solution (I) .... [illegible]
[illegible] Stock Solution (II) .... [illegible]
[illegible] Prepared Solution .... [illegible]

DISINFECTION OF FLOWING ARTESIAN WELLS

[illegible] Dry Chlorine Compounds .... [illegible]
[illegible] Controlled Flow Disinfection .... [illegible]
[illegible] Stock Solution .... [illegible]

METHOD OF PAYMENT FOR WELL DISINFECTION

[illegible] Method of Payment
Option A (Lump Sum) .... [illegible]
Option B (Time and Materials) .... [illegible]
Option C (Unit Price) .... [illegible]

Article

55. Water Samples and Analyses .... [illegible]

BACTERIOLOGICAL ANALYSES

[illegible] Bacterial .... [illegible]

ANALYSIS FOR SPECIFIC CONSTITUENTS

[illegible] Specific Constituent Analysis .... [illegible]

ANALYSIS FOR SPECIFIC PURPOSES

[illegible] Domestic Water Supply .... [illegible]
[illegible] Well and Treatment Facility Design .... [illegible]
[illegible] Irrigation Water Supply .... [illegible]
[illegible] Industrial Water Supply .... [illegible]
[illegible] Municipal Water Supply .... [illegible]

TYPES OF SAMPLES

[illegible] Bacterial Sampling .... [illegible]
[illegible] Bacterial Sampling Plus Chemical Sampling .... [illegible]
[illegible] Bacterial Sampling Plus Chemical Sampling Plus Radiological Sampling .... [illegible]
[illegible] Chemical Sampling Only .... [illegible]
[illegible] Chemical Sampling Plus Radiological Sampling .... [illegible]
[illegible] Radiological Sampling Only .... [illegible]

COLLECTION METHODS

[illegible] Bailed Sample Method .... [illegible]
[illegible] Discharge Sample Method .... [illegible]

Page

[illegible] Pumped Sample: Composite 130
[illegible] Point Sample 130
[illegible] Pumped Sample: Segregated (Drill Stem Test Sample) 130

WELL HEAD TESTS

55.000-001-000. Temperature and pH Tests Only 131
[illegible] Temperature and pH Tests Plus Gas Test 131
[illegible] Temperature and pH Tests Plus Specific Electrical Conductance Test 131
[illegible] Temperature and pH Tests Plus Specific Electrical Conductance Test Plus Alkalinity and Turbidity Tests 131
[illegible] Temperature and pH Tests Plus Gas Test Plus Specific Electrical Conductance Test 132
[illegible] Temperature and pH Tests Plus Gas Test Plus Specific Electrical Conductance Test Plus Alkalinity and Turbidity Tests 132

STANDARDS OF TEST AND SAMPLES

[illegible] Laboratory Requirements 132

METHODS OF PAYMENT FOR WATER SAMPLES AND ANALYSES

55.000-000-010. Method of Payment
Option A (Lump Sum) 133
Option B (Time and Materials) 133
Option C (Unit Price) 133

Article

56. Permanent Well and Test Hole Abandonment 133

AQUIFER SEALING CRITERIA

[illegible] Aquifer Sealing Criteria 136

PERMANENT BRIDGES

[illegible] Permanent Bridges 140

PLACEMENT OF GROUT

[illegible] Placement Operations 140
[illegible] Intermediate Seals 140
[illegible] Seal at Uppermost Aquifer 140
[illegible] Seals Placed Within Casing, Liners, Filters, etc. 141

PLACEMENT OF FILL

[illegible] Non-Producing Zones 141

SPECIAL CONDITIONS

[illegible] Pre-existing Contamination 141

WELL ABANDONMENT RECORDS

[illegible] Recording Location of Abandoned Well or Bore Hole 142

Page

METHOD OF PAYMENT FOR ABANDONMENT

56.000-000-100 Method of Payment
Option A (Lump Sum) 140
Option B (Time and Materials) 140
Option C (Unit Price) 140

Appendix A. SAMPLE NOTICE TO BIDDERS 143

Appendix B. SAMPLE PROPOSAL 145

Appendix C. UNIT PRICE PROPOSAL 147

Appendix D. BID SCHEDULE 150

Appendix E. STANDARD FORM OF AGREEMENT BETWEEN OWNER AND CONTRACTOR 153

Appendix F. STANDARD FORM—WELL ESTIMATE AND/OR WELL DRILLING CONTRACT OR REPAIR ORDER AGREEMENT 154

Appendix G. METRIC-ENGLISH UNIT CONVERSION TABLE 156

LIST OF FIGURES

Figure 1. Minimum Lengths of Cement for Different Sizes and Lengths of Casing 89
Figure 2. Plumbness Test Assembly 102
Figure 3. Centrifugal Sand Sampler 110
Figure 4. Permanent Bridge Seals 127
Figure 5. Intermediate Seal in Lined Hole 136
Figure 6. Uppermost Aquifer Seals in Well Abandonment 139

LIST OF TABLES

Table 1. Various Size Grade Scales in Common Use 66
Table 2. Line Shaft Turbines 1800 RPM 71
Table 3. Line Shaft Turbines 1200 RPM 71
Table 4. Casing Sizes—Domestic Wells 72
Table 5. Collapse Strength of Steel Pipe in Pounds Per Square Inch and Feet of Water Head 73
Table 6. Wall Thicknesses for Steel Water Well Pipe 74
Table 7. Steel Well Casing Fabricated from Standard Plate or Sheets 74
Table 8. Steel Well Casing Fabricated from "Well Casing Steel" Sheets 75
Table 9. PVC Casing 75
Table 10. PVC Casing 75
Table 11. Maximum Screen Entrance Velocities 80
Table 12. Chlorine Compound Required to Dose 100 feet of Water-Filled Well at 50 PPM 101

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Introduction

During 1969 through 1971 the U.S. Environmental Protection Agency and its predecessor the USPHS Bureau of Water Hygiene, through the Southern Regional Education Board, conducted limited surveys of individual home water supply systems in Georgia, Tennessee and Kentucky to determine the quality of drinking water from individual home supply systems and to establish the relationship of the quality of water to type supply system.

The first study, conducted in Georgia in 1969, produced unexpected results. Bacterial analyses of 760 sampled systems showed verified coliform bacteria in 308 (40%) of the samples. Included in the survey were 709 wells of which 265 (37%) showed verified coliform bacteria. A breakdown of all individual home supply systems versus verified coliform showed the following contamination: cisterns—84.2%, springs—75.0%, dug well—74.5%, bored wells—39.4%, drilled wells—18.0%, driven wells—16.7%, and jetted wells—7.1%. Secondly, from this it is obvious that there is some relationship between contamination and type of water supply. The high levels of contamination of cisterns and springs could be explained but the high contamination of wells which tap presumed bacterially pure ground water was unclear. Furthermore, data and information from Tennessee and Kentucky supported the findings in Georgia.

Historically, ground water coming from its natural environment has been considered of good sanitary quality requiring little or no treatment before use as drinking water. Consequently nearly 50 million Americans obtain their drinking water from individual home supply wells tapping this water source. The data from Georgia, Tennessee and Kentucky, however, indicate that we may have been taking the high bacterial purity of our ground water supplies for granted.

The data collected on system construction appears to have produced the answer on the bacterial contamination of wells. The method used to construct wells, and the construction details themselves affect the bacterial safety of the supply.

Deficiencies in well construction among individual supplies were found to be numerous and included: 1) insufficient and substandard well casing; 2) inadequate "formation seal" between the well casing and the bore hole; 3) poor welding of casing joints; 4) lack of sanitary covers; and 5) use of well pits to protect from freezing. Any one of these deficiencies may allow introduction of bacterial contamination from the surface to the ground water and into the supply system.

The problems facing the person receiving drinking water from an individual water supply system were brought forth during testimony in Congress on the Safe Drinking Water Act. Testimony indicated that millions of Americans may be receiving drinking water which would not meet drinking standards mandated by the Act. As designed, the standards only apply to water delivered by public water supply systems, leaving the individual home supply system unprotected. Congress expressed concern and desire that adequate protection for persons relying on individual water systems for their drinking water be made available.

Predicated upon the results of the State surveys and the testimony before Congress an unsolicited proposal for the development of well construction specifications was presented to the EPA in September of 1971 by the National Water Well Association. NWWA was concerned that the profession they represent (water well drillers and ground water specialists) was using construction procedures which could affect the public health. They felt "a set of generally accepted specifications for well construction that could be widely distributed to consulting engineers, water well contractors, municipalities, industries, agriculturalists, and individual home owners would serve to complement existing regulations, help educate the public, upgrade existing well construction techniques and thereby afford a greater protection to our ground water reserves."

During preparation of the manual, consideration was given to minimum standards already required by many States as well as pertinent suggested standards and specifications already available from other national and state associations. The manual was designed recognizing that well construction techniques will vary with six major criteria; namely, the intended use of the water, the required capacity of the well, the nature of the producing zone, the intended drilling method, and the manner in which the well construction will be paid for. Using these criteria to describe a well, alternate methods were established for the many facets of well construction such as test drilling, logging, casing, grouting, cementing, gravel packing, plumbness, alignment, development, testing, disinfection, sampling, and abandonment.

Also in the manual is a section titled "General Conditions" which is methodology by which a contractor may be engaged to construct a water well. These articles are included in this technical construction manual to inform those unfamiliar with the water well construction profession of normal procedures used when contracting for a well. The EPA feels this information should be made available to the public but recognizes that there may be other adequate alternatives.

Even though the original purpose of this project was to solve contamination problems of the individual supply system, the manual has been designed to be applicable to all types of water wells for all purposes. Proper use of this manual will result in a productive and safe water supply well.

The well construction practices outlined in this manual are supported by EPA as being complete and environmentally sound. The manual is to be a guide to well construction which provides protection of public health, safety and welfare, and protection of the ground water resources. Practices and techniques discussed are not EPA recommendations, regulations or standards required under any Federal action; they are furnished for informational and educational purposes only.

Key To Well Standards

How to Use the Key to Obtain the Appropriate Language for Preparing Water Well Specifications

The Key consists of two parts: the "Master Key", and the "Specifications Preparation Worksheet and Guide". For convenience these should be located now. They may be found in the pocket inside the back cover of this manual.

MASTER KEY

The first step in selecting the proper specifications for your water well requirements is to consult the "Master Key". This sheet contains three features. Along the left margin numbered I through VI, Well Selection Criteria are listed in the following form:

I. *Well Purpose*
II. *Design Capacity*
III. *Character of Interval Penetrated*
IV. *Character of Producing Zone*
V. *Construction of Methods*
VI. *Method of Payment*

By selecting one condition or characteristic from each of the above six criteria, the well, regardless of the requirements of the job, will be properly keyed according to conditions expected in construction of the well. Let us assume, for example, the following conditions:

From I—*Well Purpose*. The requirement is for a "municipal well"; select "C".

From II—*Design Capacity*. You require a production rate greater than 100 gpm; select "K".

From III—*Character of Interval Penetrated*. You may or may not know what to expect in the subsurface. If you do know, or have determined the nature of the subsurface (above the anticipated production zone or zones) from water-well records, or by consulting a hydrogeologist or water well contractor, the selection can be made with confidence. The character of this interval determines the type of drilling which is most appropriate, the approximate length of casing required, and other features related to well design.

In this example assume condition "L", unconsolidated.

From IV—*Character of Producing Zone.* Assuming that you know the character of the producing zone or aquifer, select condition "P", unconsolidated.

From V—*Construction Methods.* Based on the type of material to be drilled and on the type of aquifer or producing zone to be developed, assume you have selected "X.1", or the conventional fluid rotary drilling method.

From VI—*Method of Payment.* The method of payment you desire for this job, for example, is "Z", or on the basis of "time and materials".

Conditions of well construction have now been defined and can be characterized by the notation: C K L P X.1 Z. Please note that not more than six criteria should be selected; one from each list (I through VI).

The second feature of the Master Key is the display along the top of Articles which identify the major subdivisions of the Compendium. Articles 1 through 42 represent the General Conditions; Article 43 represents the Special Conditions, and Article 44 is the Glossary of Technical Terms, all of which become part of every set of specifications prepared with the exception of some domestic well applications (See Master Key). General and Special Conditions can be replaced for these types of applications by the Standard Contract Form in Appendices E and F, which contains appropriate language covering both general and special conditions. Articles 45 through 56 are, in effect, the Technical Standards, from which are drawn *only* the paragraphs as appropriate for a well defined by the "Well Selection Criteria" mentioned previously. Use of the "Well Selection Criteria" in accordance with the procedure described herein provides criteria for suggested minimum practice. A full review of all paragraphs within any one Article is recommended.

The third feature of the Master Key is the list of numbers which make up the matrix. Although the function of these numbers will be described in detail shortly, suffice it here to state, by way of introduction, that the numbers define the critical conditions of well design which control construction practices.

It should be noted that the Key has been prepared for and tested over a wide variety of possible conditions.

SPECIFICATION PREPARATION WORKSHEET AND GUIDE

The second step in selecting proper specifications for your well requirements is to fill-in the appropriate blocks of the Specifications Preparation Worksheet. As an example the Specifications Preparation Worksheet Guide (SPW Guide) has been prepared, with numbers filled-in according to the requirements of the hypothetical well discussed previously. These numbers identify specific paragraphs (Articles) in the Compendium. For example, find Article 45.000-000-100 in the Compendium. This paragraph gives standard procedures for the sampling of water from test holes. Note that each digit to the right of the Article number (45, in this example) refers to a subsection as listed across the top of the Master Key and as contained in the Compendium. The maximum number of subsections in any one Article is nine, although more (identified with double digits, 10, 11, etc.) could be added.

Please note that not all nine digits are used in some of the Article headings (for example see Article 51, Well Plumbness and Alignment), because the existing paragraphs appear to cover the most important aspects of the subject. However, other paragraphs may be added to this or other Articles at a later date if needed.

Having become familiar with the numbering and coding system with respect to the location of the paragraphs within the matrix, we now turn to the problem of compatability between construction parameters. Certain conditions may dictate specific and oftimes special design and construction considerations. Those critical conditions are isolated in the following way:

Referring to the Master Key and the previously derived well notation of C K L P X.1 Z, read across line "C" (Municipal) to Article 45. (Test Holes and Samples) vertical column 1 under the heading: "Hole Location and Purpose". Note that a "1" occupies that space. Now read across line "K" (High Yield) to Article 45, vertical column 1. Note that a "1" also occupies that space. Now reading in the same manner "L" has a "zero", "P" also a "zero", then "X.1" also a "zero" and "Z" a "0." Now compare the numbers obtained.

C = 1
K = 1
L = 0
P = 0
X.1 = 0
Z = 0

Number "1", the highest number listed, refers to the first paragraph in Article 45. This paragraph describes the basic conditions (minimum acceptable standard) stipulated by the well's notation C K L P X.1 Z. The number is inserted in column 1 of the Specifications' Preparation Worksheet as shown in the SPW Guide. This indicates that the first paragraph, or any of those higher in number within the same digit column, is acceptable, the first being the minimum standard *in this example*. The sequence of paragraphs can be considered as going from the simplest procedure or method to the most complex, implying a corresponding increase in cost.

The second, third, fourth, etc. to ninth columns of Article 45 are also to be evaluated as above. For example, in Column 2 of Article 45 (Test Holes and Samples) under the heading: "Drilling Methods", the following numbers are obtained from the Master Key:

C = 1
R = 1
L = 1
P = 1
X,1 = 6
Z = 0

Here "6" is the highest number shown and hence identifies the critical parameter which controls the minimum standard acceptable. In this hypothetical case, a municipal, high-yield, test hole is to be drilled through unconsolidated sediments and developed for production in an unconsolidated aquifer on the basis of time and materials payment. The well is to be drilled by the conventional fluid rotary drilling method, or by a method listed after Article 45.060-000-000 e.g. 45.070-000-000 (Combined Drilling and Driving), 45.080-000-000 (Cable-Tool Method). This test hole is not to be constructed by the methods indicated in lower numbered paragraphs e.g. 45.050-000-000 (Air Circulation Fluid Rotary), 45.040-000-000 (Reverse Hydraulic Rotary), 45.030-000-000 (Jetted or Hydraulic-ing) or 45.020-000-000 (Driven Well Point Method). Contractor's Choice (Article 45.010-000-000) was not selected, since in this hypothetical case a particular method of drilling was preferred by the person using the "Well Selection Criteria".

The above process should be repeated for the remainder of the columns of Article 45., as indicated for the example cited in the SPW Guide. Articles 46. through 56. should be treated in the same manner.

There are a few exceptions to the straightforward procedure of selecting appropriate Articles for establishing minimum standards. These are identified as follows:

*—Indicates that a paragraph is *not* selected, regardless of the numbers shown elsewhere in the column.

P—Indicates that an optional condition exists and a choice must be made in the indicated *paragraph* of the Compendium.

F—Indicates that blank(s) must be *filled in* according to specific requirements.

O—Indicates that *no* paragraph is appropriate at the particular entry location.

S—Indicates that paragraphs must be *selected* according to previously selected options. The "S" is to be replaced by the number of the paragraph selected.

C—Indicates that a *cross-reference* to another *Article* must be made for the correct paragraphs.

E—Indicates that the General and Special Conditions contained in the Compendium can be replaced by the Standard Contract Form in Appendices E and F. This is designed for some relatively small contracts such as for domestic wells.

The above exceptions are noted by use of a *period after* the number of the indicated paragraph, e.g., 45.000-003.F.000. Such a notation indicates that in the 3rd Article of that sequence a fill-in is required.

To summarize the generated specifications, use the SPW Guide. List them as follows in preparing specifications for a well with the criteria U K 1, F X 1 Z, meeting minimum acceptable well standards.

```
Articles 1. through 44.
        45.   1    6    2   1,P   2   3,P   1    1   1,P
        46.  1,P  1,P   1    1   1,P   0    0    0    0
        47.  1,P   4    1    1    1    1   1,P   0    0
        48.   2    3    4    3    0    1   1,P   0    0
        49.   1    5    2    2    2    1    P    2   1,P
        50.   1   1,6   2    2    1    1    4   1,P   0
        51.   1   1,P   0    0    0    0    0    0    0
        52.   4    1    1    1    1    1    4    1   1,P
        53.  4,P   1    1    3   1,P  1,6  1,P   0    0
        54.   1    1    1    1    1    1    1   1,P   0
        55.   1   1,P   2   4,P  2,P   2    1   1,P   0
        56.   1    1    1    1    1    1   1,P   0    0
```

Two features of the Key are re-emphasized here. *Any* Article in a *selected sequence of Articles* which is higher in number (or follows a specific Article) is not only an acceptable standard but is also usually of a higher standard than those Articles having lower numbers. (Note the number of zeros to the right of the Article number.) It should also be emphasized that for a very few Articles the relative position of the Article does not indicate standard level in that one technique or method may not necessarily be more appropriate than the other. For such instances selection is made on the basis of preference, *depending* upon conditions.

The standards expressed herein are those deemed the minimum *acceptable* standards which concurrently stipulate technically sound, economically efficient, and environmentally cognizant water-well construction practices.

General Preamble

The primary purposes of well construction standards are to protect the health, safety and welfare of the public; to protect ground water resources, and the environment in general, for present and future use; and to permit optimum water production from each well at minimal cost.

These standards have been prepared to accomplish these purposes and to obtain the most appropriately designed well consistent with the need for water from that well. These standards are written such that appropriate descriptive paragraphs can be adapted for use in the preparation of specifications for water-well construction. When properly used, they will result in adequate minimum specifications for water-well construction.

Throughout the standards, the general plan followed is that the higher the coded number (paragraph) used with a specific Article the higher is the quality or design of the material or construction method used. However, it is fully realized that special conditions may require specific and unique solutions. Equal weight is given a number of choices occasionally, since no one method may be any more efficient or effective than another for some geohydrologic conditions.

These standards are designed for the great majority of engineers and governmental officials whose major expertise is not in the field of well construction. These standards are designed to improve communications between the planner and the technical man in the field. They will assist planners in preparing satisfactory specifications for the majority of wells to be drilled. In instances where unusual or critical conditions occur, a person versed in the problems of well construction and design (usually a ground water geologist or hydrologist) should write the specifications.

The **NOTICE TO BIDDERS** portion of a well contract is a variable document which must be written individually for each project. A sample notice, for general guidance only, is included as Appendix A.

The **PROPOSAL FORM** is another part of the contract that should be written individually for each project. Sample proposal forms which provide general guidance are included as Appendices B and C. A **BID SCHEDULE** to accompany the unit price proposal in Appendix C is presented in Appendix D.

The **BID BOND** and the **PERFORMANCE BOND** are often included as portions of the contract. If used they should be written or completed in accordance with the instructions of the customer or his bonding agency.

The Standard Form Agreement is the major contract document. For general reference a sample agreement is included as Appendices E and F.

Because of the growing use of the metric system of measurement a metric-English unit conversion table is included as Appendix G.

Before entering into any discussion of construction standards it is imperative that each person concerned with the design and actual construction of a facility be reminded of the legal and moral responsibility of the employer and his supervisor to provide employees with a safe working environment. Employers have been provided with sets of safety standards, the most comprehensive of which are those of the U.S. Department of Labor, prepared under the Occupational Safety and Health Act of 1970. Any prospective designer, planner, or contractor should avail himself of the safety standards for his occupation and become familiar with their contents.

Anyone acquainted with manual labor may be familiar with the old saying that there is a proper tool for every job. It is the purpose of safety programs, through training, supervision, and inspection, to prescribe that tool, and to assure that it is used and kept in the best possible condition.

The water-related industries, especially the well construction industry, have more than their share of occupational hazards and as such require alertness and diligence on the part of all personnel to avoid hazardous situations. The following is a checklist of the categories for which there are standards for the industry. Of particular concern are the sections on dangerous vapors and electrocution, for these hazards are the ones most often overlooked in daily operations:

- Safety Training
- General Housekeeping of Construction Site
- Personal Protective Equipment Both Individual and Site
- Availability of Medical Supplies, Personnel and Facilities
- Sanitation
- Occupational Noise Exposure
- Exposure to Dangerous Gases, Vapors, Fumes, Dusts and Mists
- Illumination
- Protective Barriers and Signs
- Fire Protection and Prevention
- Storage of Flammable and Combustible Liquids
- Use and Storage of Explosives
- Use and Care of Hand and Power Tools
- Use and Care of Welding and Cutting Equipment
- Electrical Hazards
- Construction and Use of Ladders and Scaffoldings
- Use of Mechanical, Hoisting, Lifting and Carrying Devices
- Excavations, Trenching and Shoring

Specific standards for any item in the above list can be obtained from an appropriate state agency or the U.S. Department of Labor, Washington, D.C.

Section 1

General Conditions

Article 1.100–000–000. ***Definition of Terms.*** Whenever used in these General Conditions or in the other Contract Documents, the following terms shall have the meanings indicated, and these shall be applicable to both the singular and plural thereof:

Agreement. The written agreement between the OWNER and the CONTRACTOR, as indicated by the Bid and Bonds.

Application for Payment. The form furnished by the OWNER which is to be used by the CONTRACTOR in requesting incremental (progress) payments and which is to include the schedule of values required by Article 26.1 and an affidavit of the CONTRACTOR. The affidavit shall stipulate that progress payments theretofore received from the OWNER on account of the Work have been applied by the CONTRACTOR to discharge in full all of the CONTRACTOR'S obligations incurred in connection with the work covered by all prior Applications for Payment.

Bid. The offer or proposal of the Bidder submitted on the prescribed form setting forth the prices for the Work to be performed.

Bidder. Any person, firm or corporation submitting a Bid for the Work.

Bonds. Bid, performance, and payment bonds and other instruments of security, furnished by the CONTRACTOR and his surety in accordance with the Contract Documents.

Change Order. A written order to the CONTRACTOR signed by the OWNER authorizing an addition, deletion or revision in the Work, or an adjustment in the Contract Price or the Contract Time issued after execution of the Agreement.

Contract Documents. The Agreement, Specifications, Drawings, Addenda (whether or not issued prior to opening of bids or execution of the Agreement) and Modifications.

Contract Price. The total moneys payable to the CONTRACTOR under the Contract Documents.

Contract Time. The number of calendar days stated in the Agreement for the completion of the Work.

CONTRACTOR. The person, firm or corporation with whom the OWNER has executed the Agreement.

Drawings. The drawings and plans which show the character and scope of the Work to be performed and which have been prepared or approved by the Owner and are referred to in the Contract Documents.

Field Order. A written order issued by the OWNER or his agent which clarifies or interprets the Contract Documents in accordance with Article 14.1 or orders minor changes in the work in accordance with Article 20.2.

Modification. (a) A written amendment of the Contract Documents signed by both parties, (b) a Change Order, (c) a written clarification or interpretation issued by the OWNER or his agent in accordance with Article 14.1 or (d) a written order for a minor change or alteration in the work issued by the OWNER or his representative pursuant to Article 20.2. A Modification may only be issued after execution of the Agreement.

OWNER. A public body or authority, corporation, association, partnership, or individual for whom the Work is to be performed.

Project. The entire construction to be performed as provided in the Contract Documents.

PROJECT REPRESENTATIVE. The authorized representative of the OWNER who is assigned to the Project or any parts thereof.

Shop Drawings. All drawings, diagrams, illustrations, brochures, schedules and other data which are prepared by the CONTRACTOR, a Subcontractor, manufacturer, supplier or distributor and which illustrate the equipment, material or some portion of the Work.

Specifications. The Instructions to bidders, these General Conditions, the Special Conditions and the Technical Provisions.

Subcontractor. An individual, firm or corporation having a direct contract with the CONTRACTOR or with any other Subcontractor for the performance of a part of the Work at the site.

Substantial Completion. The date as certified by the OWNER or his agent when the construction of the Project or a specified part thereof is sufficiently complete, in accordance with the Contract Documents, so that the Project or specified part can be utilized for the purposes for which it was intended; or if there be no such certification, the date when final payment is due in accordance with Article 30.3.

Superintendent. Contractor's representative.

Work. Any and all obligations, duties and responsibilities necessary to the successful completion of the Project assigned to or undertaken by the CONTRACTOR under the Contract Documents, usually including the furnishing of all labor, materials, equipment and other incidentals.

Article 2
Award, Execution of Documents, Delivery of Bonds, etc.

2.100-000-000. The award of the contract, if it is awarded, will be to the lowest responsible Bidder whose qualifications indicate that the award will be in the best interest of the OWNER and whose proposal complies with all the prescribed requirements. No award will be made until the

OWNER has concluded such investigations as he deems necessary to establish the responsibility, qualifications and financial ability of the Bidders to do the Work in accordance with the Contract Documents to the satisfaction of the OWNER within the time prescribed. The OWNER reserves the right to reject the Bid of any Bidder who does not meet such qualifications to the OWNER'S satisfaction. In analyzing Bids, the OWNER may take into consideration alternates and unit prices, if requested by the Bid forms. If the contract is awarded, the OWNER shall give the successful Bidder written notice of the award within thirty days after the opening of the Bids.

2.200-000-000. At least three counterparts of the Agreement and of such other Contract Documents as practicable shall be signed by the OWNER and the CONTRACTOR. The OWNER shall identify those portions of the Contract Documents not so signed and such identification shall be binding on both parties. The OWNER and the CONTRACTOR shall each receive an executed counterpart of the Contract Documents.

2.300-000-000. Simultaneously with the execution of the Agreement, the CONTRACTOR shall deliver to the OWNER the required Bonds.

2.400-000-000. Failure of the successful Bidder to execute the Agreement and deliver the required Bonds within ten days of the notice of the award shall be just cause for the OWNER to annul the award and declare the Bid and any guarantee thereof forfeited.

Article 3
Progress and Submission Schedules; Preconstruction Conference; Time for Starting the Work

3.100-000-000. Within ten days after execution of the Agreement, the CONTRACTOR shall submit to the OWNER for approval, an estimated progress schedule indicating the starting and completion dates of the various stages of the Work, and a schedule of Shop Drawing submissions. At least ten days prior to submitting the first Application for Payment he shall also submit a schedule of values as required by Article 26.1.

3.200-000-000. Before starting the Work, a conference will be held to review the above plans and schedules, to establish procedures for handling Shop Drawings and other submissions; for processing Applications for Payment; and to establish a working understanding between parties as to the conduct of the Project. Present at the conference will be the OWNER, the Project Representative, the CONTRACTOR and the Superintendent.

3.300-000-000. Prior to starting the Work the CONTRACTOR shall furnish the OWNER and PROJECT REPRESENTATIVE certificates of insurance as required by Article 34.

3.400-000-000. The CONTRACTOR shall start the Work within ten days of the date on which the Agreement is executed and delivered, or on such other date, as may be specified in the Agreement. However, at the time of the execution and delivery of the Agreement the **OWNER** may give the **CONTRACTOR** a written notice to proceed, stating a different date on which it is expected that the **CONTRACTOR** will start the Work, but such date shall not be more than thirty days after the date of execution and delivery of the Agreement. A copy of the notice to proceed shall be sent to the **PROJECT REPRESENTATIVE.** No work shall be done prior to the date on which the Work is to start.

3.500-000-000. The Contract Time shall commence on the date the work is to start as provided in Article 3.4.

Article 4
Correlation, Interpretation and Intent of Contract Documents

4.100-000-000. It is the intent of the Specifications and Drawings to describe the complete Project to be constructed in accordance with the Contract Documents.

The Contract Documents comprise the entire Agreement between the **OWNER** and the **CONTRACTOR.** They may be altered only by a Modification.

4.200-000-000. The Contract Documents are complementary; what is called for by one is as binding as if called for by all. If the **CONTRACTOR** finds a conflict, error or discrepancy in the Contract Documents, he shall call it to the **OWNER'S** attention in writing before proceeding with the Work affected thereby. In resolving such conflicts, errors and discrepancies, the documents shall be given precedence in the following order: Agreement, Specifications, Drawings. Within the Specifications the order of precedence shall be as follows: Special Conditions, Instruction to Bidders, General Conditions, Technical Provisions. Figure dimensions on Drawings shall govern over scale dimensions, and detailed Drawings shall govern over general Drawings. Any Work that may reasonably be inferred from the Specifications or Drawings as being required to produce the intended result shall be supplied whether or not it is specifically called for. Work, materials or equipment described in words which when so applied have a well-known technical or trade meaning shall be deemed to refer to such recognized standards. The **CONTRACTOR** assumes full responsibility for having familiarized himself with the nature and extent of the Contract Documents, Work, locality, and local conditions that may in any manner affect the Work to be done.

Article 5
Ownership and Copies of Documents; Record Documents

5.100-000-000. All specifications, Drawings and copies thereof furnished by the **OWNER** shall remain his property. They shall not be used on another Project, and with the exception of those sets which have been furnished in connection with the execution of the Agreement, shall be returned to him on request upon completion of the Project.

5.200-000-000. The OWNER shall furnish to the **CONTRACTOR** up to ten copies of the Specifications and Drawings as are reasonably necessary for the execution of the Work. Additional copies will be furnished, upon request, at the cost of reproduction.

5.300-000-000. The **CONTRACTOR** shall keep one record copy of all Specifications, Drawings, Addenda, Modifications, and Shop Drawings at the site in good order and annotated to show all changes made during the construction process. These shall be available to the **PROJECT REPRESENTATIVE** and shall be delivered to him for the **OWNER** upon completion of the Project.

Article 6
Work by Others

6.100-000-000. The OWNER may perform additional work related to the Project by himself, or he may let other direct contracts therefor which shall contain General Conditions similar to these. The **CONTRACTOR** shall afford the other contractors who are parties to such direct contracts (or the **OWNER**, if he is performing the additional work himself), reasonable opportunity for the introduction and storage of materials and equipment and the execution of work, and shall properly connect and coordinate his Work with theirs.

6.200-000-000. If any part of the **CONTRACTOR'S** Work depends for proper execution or results upon the work of any other contractor (or the **OWNER**), the **CONTRACTOR** shall inspect and promptly report to the **PROJECT REPRESENTATIVE** in writing any defects or deficiencies in such work that render it unsuitable for proper execution and results. His failure to so report shall constitute an acceptance of the work as fit and proper for the relationship of his Work except as to defects and deficiencies which may appear in the other work after the execution of his Work.

6.300-000-000. The CONTRACTOR shall do all cutting, fitting and patching of his Work that may be required to make its several parts come together properly and fit to receive or be received by such other work. The **CONTRACTOR** shall not endanger any work of others by cutting, excavating or otherwise altering their work and will only cut or alter their work with the written consent of the **OWNER**.

6.400-000-000. If the performance of additional work by other contractors or the **OWNER** is not noted in the Contract Documents prior to the award of the contract, written notice thereof shall be given to the **CONTRACTOR** prior to starting any such additional work. If the **CONTRACTOR** believes that the performance of such additional work by the **OWNER** or others involves him in additional expense or entitles him to an extension of the Contract Time, he may make a claim therefor as provided in Articles 21 and 23.

Article 7
Subcontracts

7.100-000-000. Prior to the execution and delivery of the Agreement, the successful Bidder will submit to the OWNER for acceptance a list of the names of Subcontractors and such other persons and organizations (including those who are to furnish materials or equipment fabricated to a special design) proposed for those portions of the Work as to which the identity of the Subcontractors and other persons and organizations must be submitted as specified in the Contract Documents. Prior to the execution and delivery of the Agreement, the OWNER shall notify the successful Bidder in writing if the OWNER, after due investigation, has reasonable objection to any Subcontractor, person or organization on such list. The failure of the OWNER to make objection to any Subcontractor, person or organization on the list prior to the execution and delivery of the Agreement shall constitute an acceptance of such Subcontractor, person or organization. Acceptance of any such Subcontractor, person or organization shall not constitute a waiver of any right of the OWNER to reject defective Work, material or equipment, or Work, material or equipment not in conformance with the requirements of the Contract Documents.

7.200-000-000. If, prior to the execution and delivery of the Agreement, the OWNER has reasonable objection to and refuses to accept any Subcontractor, person or organization on such list, the successful Bidder may, prior to such execution and delivery, either (i) submit an acceptable substitute without an increase in his Bid Price or (ii) withdraw his bid without forfeiture of his Bid security. If, after the execution and delivery of the Agreement, the OWNER refuses to accept any Subcontractor, person or organization on such list, the CONTRACTOR shall submit an acceptable substitute and the Contract Price shall be increased or decreased by the difference in cost occasioned by such substitution and an appropriate Change Order shall be issued; however, no such increase in the Contract Price shall be allowed in respect to any substitution unless the CONTRACTOR has acted promptly and reasonably in submitting a name with respect thereto prior to the execution and delivery of the Agreement.

7.300-000-000. The CONTRACTOR shall not employ any Subcontractor (whether initially or as a substitute) against whom the OWNER may have reasonable objection, nor shall the CONTRACTOR be required to employ any Subcontractor against whom he has reasonable objection. The CONTRACTOR shall not make any substitution for any Subcontractor who has been accepted by the OWNER unless the OWNER determines that there is good cause for doing so.

7.400-000-000. The CONTRACTOR shall be fully responsible for all acts and omissions of his Subcontractor and of persons directly or indirectly employed by them and of persons for whose acts any of them may be liable to the same extent that he is responsible for the acts and omissions of persons directly employed by him. Nothing in the Contract Documents shall create any contractual relationship between any Subcontractor and OWNER or any obligation on the part of the OWNER to pay or to see to the payment of any Moneys due any Subcontractor, except as may otherwise be required by law. The OWNER may furnish to any Subcontractor, to the extent practicable, evidence of amounts paid to the CONTRACTOR on accounts of specific work done in accordance with the schedule of values.

7.500-000-000. The divisions and sections of the Specifications and the identifications of any drawings shall not control the Contractor in dividing the Work among Subcontractors or delineating the Work to be performed by any trade.

7.600-000-000. The CONTRACTOR agrees to specifically bind every Subcontractor to all of the applicable terms and conditions of the Contract Documents. Every Subcontractor, by undertaking to perform any of the Work, shall thereby automatically be deemed bound by such terms and conditions.

7.700-000-000. All Work performed for the CONTRACTOR by a Subcontractor shall be pursuant to an appropriate agreement between the CONTRACTOR and the Subcontractor which shall contain provisions that waive all rights the contracting parties may have against one another for damages caused by fire or other perils covered by insurance provided in accordance with Article 36, except such rights as they may have to the proceeds of such insurance held by the OWNER as trustee under Article 36.5. The CONTRACTOR will pay each Subcontractor a just share of any insurance moneys received by the CONTRACTOR under Article 36.

Article 8
Materials, Equipment and Labor; Substitute Material or Equipment

8.100-000-000. The CONTRACTOR shall provide and pay for materials, equipment, labor, transportation, construction equipment and machinery, tools, appliances, fuel, power, light, heat, telephone, water and sanitary facilities and all other facilities and incidentals necessary for the execution, testing, initial operation and completion of the Work.

8.200-000-000. All materials and equipment furnished under the contract shall be new. If required by the OWNER, the CONTRACTOR will furnish satisfactory evidence as to the kind and quality of materials and equipment.

8.300-000-000. If it is indicated in the Specifications that the CONTRACTOR may furnish or use a substitute that is equal to any material or equipment specified, and if the CONTRACTOR wishes to furnish or use a proposed substitute, he shall promptly after the award of the contract, make written application to the OWNER for approval of such a substitute, certifying in writing that the proposed substitute will perform adequately the duties imposed by the general design, be similar and of equal substance to that specified, and be suited to the same use and capable of performing the same function as that specified. No substitute shall be ordered or installed without the written approval of the OWNER who shall be the judge of its equality.

Article 9
Patent Fees and Royalties

The CONTRACTOR shall pay all license fees and royalties and assume all costs incidental to the use of any invention, design, process or device which is the subject of patent rights or copyrights held by others. He shall indemnify and hold harmless the OWNER and anyone directly or indirectly employed by him from and against all claims, damages, losses and expenses (including attorneys' fees) arising out of any infringement of such rights during or after completion of the Work, and shall defend all such claims in connection with any alleged infringement of such rights.

Article 10
Permits, Laws, Taxes and Regulations

10.100-000-000. The CONTRACTOR shall give all notices and comply with all laws, ordinances, rules, and regulations applicable to the Work. If the CONTRACTOR observes that the Specifications or Drawings are at variance therewith, he shall give the OWNER prompt written notice thereof, and any necessary changes shall be adjusted by an appropriate Modification. If the CONTRACTOR performs any Work knowing it to be contrary to such laws, ordinances, rules and regulations, and without such notice to the OWNER, he shall bear all costs arising therefrom.

10.200-000-000. The CONTRACTOR shall pay all sales, consumer, use and other similar taxes required by the law of the place where the Work is to be performed.

Article 11
Availability of Lands; Physical and Subsurface Conditions; Reference Points

11.100-000-000. The OWNER shall provide, as indicated in the Contract Documents and not later than the date when needed by the CONTRACTOR, the lands upon which the Work is to be done, rights-of-way for access thereto, and such other lands which are designated for the use of the CONTRACTOR. Easements for permanent structures or permanent changes in existing facilities will be secured and paid for by the OWNER, unless otherwise specified in the Contract Documents. If the CONTRACTOR believes that any delay in the OWNER'S furnishing these lands or providing such easements entitles him to an extension of the Contract Time, he may make a claim therefore as provided in Article 23. The CONTRACTOR shall provide to all additional lands access thereto that may be required for temporary construction facilities or storage of materials and equipment

11.200-000-000. The OWNER shall furnish to the CONTRACTOR copies of all available boundary surveys and subsurface tests, well logs, test drilling data and records of existing wells and other excavations that he may possess.

11.300-000-000. The CONTRACTOR shall promptly notify the OWNER or his representative in writing of any subsurface or latent physical conditions at the site differing materially from those indicated in the Contract Documents. The PROJECT REPRESENTATIVE shall promptly investigate those conditions and advise the OWNER in writing if further surveys or subsurface tests are necessary. Promptly thereafter, the OWNER shall obtain the necessary additional surveys and tests and furnish copies to the CONTRACTOR. If the OWNER finds that the results of such surveys or tests indicate subsurface or latent physical conditions differing significantly from those indicated in the Contract Documents, a Change Order shall be issued incorporating the necessary revisions.

11.400-000-000. The OWNER shall establish such general reference points as in his judgment will enable the CONTRACTOR to proceed with the Work. The CONTRACTOR shall be responsible for the layout of the Work and shall protect and preserve the established reference points and make no changes or relocations without the prior written approval of the OWNER. He shall report to the OWNER whenever any reference point is lost or destroyed or requires relocation because of necessary changes in grades or locations. The CONTRACTOR shall replace and accurately relocate all reference points so lost, destroyed or moved.

Article 12
Use of Premises

12.100-000-000. The CONTRACTOR shall confine his equipment, storage of materials and equipment, and the operations of his employees to areas permitted by law, ordinances, permits, or the requirements of the Contract Documents, and shall not unreasonably encumber the premises with materials or equipment.

12.200-000-000. The CONTRACTOR shall not load or permit any part of the structure to be loaded with weights that will endanger the structure, nor shall he subject any part of the Work to stresses or pressures that will endanger it.

Article 13
OWNER'S *Status During Construction*

13.100-000-000. The OWNER and the CONTRACTOR are those persons or organizations identified as such in the Agreement and are referred to throughout the Contract Documents as if singular in number and masculine in gender.

13.200-000-000. The PROJECT REPRESENTATIVE shall be the OWNER'S representative during the construction period. All instructions of the OWNER to the CONTRACTOR shall be issued through the PROJECT REPRESENTATIVE. The duties and responsibilities and the limitations of authority of the PROJECT REPRESENTATIVE as the OWNER'S representative during construction are set forth in Articles 1 through 42 of these General Conditions and shall not be extended without written consent of the OWNER.

13.300-000-000. The OWNER or his representative shall make periodic visits to the site to observe the progress and quality of the executed Work and to determine, in general, if the Work is proceeding in accordance with the Contract Documents. He shall not be required to make exhaustive or continuous on-site inspections to check the quality or quantity of the Work nor will he be responsible for the construction means, methods, techniques, sequences or procedures, or the safety precautions incident thereto. His efforts shall be directed toward providing assurance for the OWNER that the completed Project will conform to the requirements of the Contract Documents, but he shall not be responsible for the CONTRACTOR'S failure to perform the Work in accordance with the Contract Documents. On the basis of his on-site observations as an experienced and qualified professional, he shall keep the OWNER informed of the progress of the work and shall endeavor to guard the OWNER against defects and deficiencies in the Work of contractors.

13.400-000-000. The OWNER shall have authority to disapprove of or reject Work which is defective; i.e., it is unsatisfactory, faulty or defective, or does not conform to the requirements of the Contract Documents or does not meet the requirements of any inspection, test or approval procedure referred to in Article 16.1. He shall also have authority to require special inspection or testing of the Work as provided in Article 19.3, whether or not the Work is fabricated, installed or completed. The OWNER must disapprove or reject any method of work within ten days of its initiation or it will be construed to indicate his approval.

13.500-000-000. The OWNER shall provide one or more fulltime Resident Project Representatives to assist in carrying out the responsibilities at the site. The duties, responsibilities and limitations of authority of any such Resident Project Representative shall be set forth in an exhibit to be incorporated in the Contract Documents. In the event that his duties and responsibilities are not set forth in the Contract Documents, they shall be as specified herein for the OWNER.

13.600-000-000. Neither the PROJECT REPRESENTATIVE'S authority to act under this Article nor any decision made by him in good faith either to exercise or not exercise such authority shall give rise to any duty or responsibility of the OWNER to the CONTRACTOR, any Subcontractor, any of their agents or employees or any other person performing any of the Work.

Article 14
PROJECT REPRESENTATIVE'S
Interpretations and Decisions

14.100-000-000. The PROJECT REPRESENTATIVE shall issue with reasonable promptness such written clarifications or interpretations (in the form of drawings or otherwise) as he may deem necessary for the proper execution of the Work, such clarifications and interpretations to be consistent with or reasonably inferable from the overall intent of the Contract Documents. If the CONTRACTOR believes that a written clarification and interpretation entitles him to an increase in the Contract Price, he may make a claim therefor as provided in Article 21.

14.200-000-000. The PROJECT REPRESENTATIVE shall be the initial interpreter of the terms and conditions of the Contract Documents and the judge of the performance thereunder. In his capacity as interpreter and judge he will exercise his best efforts to insure faithful performance by both the OWNER and the CONTRACTOR. He will not show partiality to either and shall not be liable for the result of any interpretation or decision rendered in good faith. Claims, disputes and other matters relating to the execution and progress of the Work or the interpretation thereof or performance under the Contract Documents shall be referred initially to the OWNER for decision, which he shall render in writing within a reasonable time.

14.300-000-000. Either the OWNER or the CONTRACTOR may demand arbitration with respect to any such claim, dispute or other matter that has been referred to the PROJECT REPRESENTATIVE, except any which have been waived by the making or acceptance of final payment as provided in Article 31.2. Such arbitration is to be in accordance with Article 41. However, no demand for arbitration of any such claim, dispute or other matter shall be made until the earlier of (a) the date on which the PROJECT REPRESENTATIVE has rendered his decision or (b) the tenth day after the parties have presented their evidence to the PROJECT REPRESENTATIVE, if he has not rendered his written decision before that date. No demand for arbitration shall be made later than thirty days after the date on which the PROJECT REPRESENTATIVE rendered his written decision in respect to the claim, dispute or other matter as to which arbitration is sought; and the failure to demand arbitration within said thirty days' period shall result in the PROJECT REPRESENTATIVE'S decision being final and binding upon the **OWNER** and the **CONTRACTOR**. If the **PROJECT REPRESENTATIVE** renders a decision after arbitration proceedings have been initiated such decision may be entered as evidence but shall not supersede the arbitration proceedings, except where the decision is acceptable to the parties concerned.

Article 15
Shop Drawings and Samples

15.100-000-000. After checking and verifying all field measurements, the **CONTRACTOR** shall submit to the **OWNER** or his representative for approval, in accordance with the accepted schedule of Shop Drawings submissions, five copies (or at the **OWNER'S** option, one reproducible copy) of all Shop Drawings, which shall have been checked by and stamped with the approval of the **CONTRACTOR** and identified as the **PROJECT REPRESENTATIVE** may require. The data shown on the Shop Drawings shall be complete with respect to dimensions, design criteria, materials of construction, and the like to enable the **PROJECT REPRESENTATIVE** to review the information as required.

15.200-000-000. The **CONTRACTOR** shall also submit to the **OWNER** for approval, with such promptness as to cause no delay in the Work, all samples required by the Contract Documents. All samples shall have been checked by and stamped with the approval of the **CONTRACTOR**, identified clearly as to material, manufacturer, pertinent catalog numbers, and the use for which intended.

15.300-000-000. At the time of each submission, the **CONTRACTOR** shall, in writing, call the **OWNER'S** attention to any deviations that the Shop Drawings or sample may have from the requirements of the Contract Documents.

15.400-000-000. The **PROJECT REPRESENTATIVE** shall check and approve with reasonable promptness Shop Drawings and samples, but his checking and approval shall be only for conformance with the design concept of the Project and for compliance with the information given in the Contract Documents The approval of a separate item, as such, will not indicate approval of the assembly in which the item functions. The **CONTRACTOR** shall make any corrections required by the **PROJECT REPRESENTATIVE** and shall return the required number of corrected copies of Shop Drawings and resubmit new samples until approved. The **CONTRACTOR** shall direct specific attention in writing or on resubmitted Shop Drawings to revisions other than those called for by the **PROJECT REPRESENTATIVE** on previous submissions.

15.500-000-000. No work requiring a Shop Drawing or sample submission shall be commenced until the submission has been approved by the **PROJECT REPRESENTATIVE**.

15.600-000-000. The **OWNER'S** approval of Shop Drawings or samples shall not relieve the **CONTRACTOR** from his responsibility for any deviations from the requirements of the Contract Documents unless the **CONTRACTOR** has in writing called the **OWNER**'s attention to such deviations at the time of submission and the **OWNER** has given written approval to the specific deviation, nor shall any approval by the **OWNER** relieve the **CONTRACTOR** from responsibility for errors or omissions in the Shop Drawings.

Article 16
Tests and Inspections

16.100-000-000. If the Contract Documents, laws, ordinances, rules, regulations or orders of any public authority having jurisdiction require any Work to specifically be inspected, tested, or approved by someone other than the **CONTRACTOR**, the **CONTRACTOR** shall give the **OWNER** timely notice of readiness therefor. The **CONTRACTOR** shall furnish the **OWNER** the required certificates of inspection, testing or approval. All such tests, will be in accordance with the methods prescribed by the American Society for Testing and Materials or such other applicable organization as may be required by law or the Contract Documents. If any such Work required so to be inspected, tested or approved is covered up without written approval or consent of the **OWNER**, it must, if directed by the **PROJECT REPRESENTATIVE**, be uncovered for observation at the **CONTRACTOR**'s expense. The cost of all such inspections, tests and approvals shall be borne by the **CONTRACTOR** unless otherwise provided.

16.200-000-000. Any Work which fails to meet the requirements of any such test, inspection or approval and any Work which meets the requirements of any such test or approval but does not meet the requirements of the Contract Documents shall be considered defective. Such defective Work may be rejected, corrected or accepted as provided in Article 25.

16.300-000-000. Neither observations by the **OWNER**, nor inspections, tests or approvals by persons other than the **CONTRACTOR** shall relieve the **CONTRACTOR** from his obligations to perform the Work in accordance with the requirements of the Contract Documents.

Article 17
CONTRACTOR'S
Supervision and Superintendence

17.100-000-000. The **CONTRACTOR** shall supervise and direct the Work efficiently and with his best skill and attention. He shall be solely responsible for the means, methods, techniques, sequences and procedures of construction. Before undertaking the Work he shall carefully study and compare the Contract Documents and check and verify all figures shown thereon and all field measurements. He shall at once report in writing to the **OWNER** any conflict, error or discrepancy which he may discover.

The CONTRACTOR shall be responsible to see that the finished Work complies accurately with the Contract Documents.

17.200-000-000. The CONTRACTOR shall keep on the Work at all times during its progress a resident superintendent satisfactory to the OWNER. The superintendent will be the CONTRACTOR'S representative at the site and shall have authority to act on behalf of the CONTRACTOR. All communications given to the superintendent shall be as binding as if given to the CONTRACTOR.

17.300-000-000. The CONTRACTOR shall provide competent, suitably qualified personnel to survey and lay out the Work and perform construction as required by the Contract Documents. He will at all times maintain good discipline and order among his employees at the site.

17.400-000-000. The OWNER shall not be responsible for the acts or omissions of the CONTRACTOR, or any Subcontractors, or any of his or their agents or employees, or any other persons performing any of the Work.

Article 18
Safety and Protection; Emergencies

18.100-000-000. The CONTRACTOR shall be responsible for initiating, maintaining and supervising all safety precautions and programs in connection with the Work. He shall take all necessary precautions for the safety of, and shall provide the necessary protection to prevent damage, injury, or loss to:

18.1.100-000-000. All employees on the Work and other persons who may be affected thereby.

18.1.200-000-000. All the Work and all materials or equipment to be incorporated therein, whether in storage on or off the site, and,

18.1.300-000-000. Other property at the site or adjacent thereto, including trees, shrubs, lawns, walks, pavements, roadways, structures and utilities not designated for removal, relocation or replacement in the course of construction.

The CONTRACTOR shall comply with all applicable laws, ordinances, rules, regulations and orders of any public body having jurisdiction for the safety of persons or property or to protect them from damage, injury or loss. He shall erect and maintain, as required by the conditions and progress of the Work, all necessary safeguards for safety and protection, including posting danger signs and other warnings against hazards and promulgating safety regulations. He shall notify owners of adjacent utilities when prosecution of the Work may affect them. When the use or storage of explosives or other hazardous materials is necessary for the prosecution of the Work, the CONTRACTOR shall exercise the utmost care and shall carry on such activities under the supervision of properly qualified personnel. All damage, injury or loss to any property referred to in

Articles 18.1.2 or 18.1.3 caused, directly or indirectly, in whole or in part, by the CONTRACTOR, a Subcontractor or anyone directly or indirectly employed by any of them or anyone for whose acts any of them may be liable, shall be remedied by the CONTRACTOR, except damage or loss attributable to the fault of drawings or specifications or to the acts or omissions of the OWNER or anyone employed by *either of them* or for whose acts either of them may be liable, and not attributable to the fault or negligence of the CONTRACTOR.

18.200-000-000. The CONTRACTOR shall designate a responsible member of his organization at the site whose duty shall be the prevention of accidents. This person shall be the CONTRACTOR'S superintendent unless otherwise designated in writing by the CONTRACTOR to the OWNER.

18.300-000-000. In emergencies affecting the safety of persons or the Work or property at the site or adjacent thereto, the CONTRACTOR, without special instruction or authorization from the OWNER, is obligated to act, at his discretion, to prevent threatened damage, injury or loss. He shall give the OWNER prompt written notice of any significant changes in the Work or deviations from the Contract Documents caused thereby, and a Change Order shall thereupon be issued covering the changes and deviations involved. If the CONTRACTOR believes that additional work done by him in an emergency which arose from causes beyond his control entitles him to an increase in the Contract Price or an extension of the Contract Time, he may make a claim therefor as provided in Articles 21 and 23.

Article 19
Access to the Work; Uncovering Finished Work

19.100-000-000. The OWNER and his representatives and other representatives of the OWNER shall at all times have access to the Work. The CONTRACTOR shall provide proper facilities for such access and observation of the Work and also for any inspection, or testing thereof by others.

19.200-000-000. If any Work is covered contrary to the request of the OWNER, it must, if requested by the OWNER, be uncovered for his observation and replaced at the CONTRACTOR'S expense.

19.300-000-000. If any Work has been covered which the OWNER has not specifically requested to observe prior to its being covered, or if the PROJECT REPRESENTATIVE considers it necessary or advisable that covered Work be inspected or tested by others, the CONTRACTOR, at the OWNER'S request, will uncover, expose or otherwise make available for observation, inspection or testing as the OWNER may require, that portion of the Work in question, furnishing all necessary labor, material and equipment. If it is found that such Work is defective or does not meet the requirements of the Contract Documents, the CONTRACTOR will bear all the expenses of such uncovering, exposure, observation, inspection and testing as the **OWNER** may require, of that portion of the Work in question, furnishing all necessary labor, material and equipment. If it is found that such Work is defective or does not meet the requirements of the Contract Documents, the **CONTRACTOR** shall bear all the expenses of such uncovering, exposure, observation, inspection and testing and of satisfactory reconstruction, including compensation for additional professional services, and an appropriate Change Order shall be issued deducting all such costs from the Contract Price. If, however, such Work is found to be nondefective and meets the requirements of the Contract Documents, the **CONTRACTOR** shall be allowed an increase in the Contract Price or extension of the Contract Time directly attributable to such uncovering, exposure, observation, inspection, testing and reconstruction if he makes a claim therefor as provided in Article 21 and 23.

Article 20
Changes in the Work

20.100-000-000. Without invalidating the Agreement, the **OWNER** may, at any time or from time to time, order additions, deletions or revisions in the Work; these will be authorized by Change Orders. Upon receipt of a Change Order, the **CONTRACTOR** will proceed with the Work involved. All such Work shall be executed under the applicable conditions of the Contract Documents. If any Change Order causes an increase or decrease in the Contract Price or an extension or shortening of the Contract Time, an equitable adjustment shall be made as provided in Article 21 or Article 23.

20.200-000-000. The **OWNER** may authorize minor changes or alterations in the Work not involving extra cost and not inconsistent with the overall intent of the Contract Documents. These may be accomplished by a Field Order. If the **CONTRACTOR** believes that any minor change or alteration authorized by the **OWNER** entitles him to an increase in the Contract Price, he may make a claim therefor as provided in Article 21.

20.300-000-000. Additional work performed by the **CONTRACTOR** without authorization of a Change Order shall not entitle him to an increase in the Contract Price or an extension of the Contract Time, except in the case of an emergency as provided in Article 10.3 and except as provided in Articles 16.1, 19.3 and 20.2.

20.400-000-000. The **OWNER** shall execute any appropriate Change Order prepared by the **PROJECT REPRESENTATIVE** covering changes in the Work to be performed as provided in Article 11.4, and Work performed in an emergency as provided in Article 10.3 and any other claim of the **CONTRACTOR** for a change in the Contract Time or the Contract Price which is approved by the **PROJECT REPRESENTATIVE**.

20.500-000-000. It is the **CONTRACTOR'S** responsibility to notify his surety of any changes affecting the general scope of the Work or change in the Contract Price and the amount of the applicable Bonds shall be adjusted accordingly. The **CONTRACTOR** will furnish proof of such adjustment to the **OWNER**.

Article 21
Change of Contract Price

21.100-000-000. The Contract Price constitutes the total compensation payable to the **CONTRACTOR** for performing the Work. All duties, responsibilities, and obligations assigned to or undertaken by the **CONTRACTOR** shall be at his expense without change in the Contract Price.

21.200-000-000. The Contract Price may only be changed by a Change Order. If the **CONTRACTOR** is entitled by the Contract Documents to make a claim for an increase in the Contract Price, his claim shall be in writing and delivered to the **OWNER** within fifteen days of the occurrence of the event giving rise to the claim. All claims for adjustments in the Contract Price shall be determined by the **PROJECT REPRESENTATIVE** if the **OWNER** and **CONTRACTOR** cannot otherwise agree on the amount involved. Any change in the Contract Price resulting from any such claim shall be incorporated in a Change Order.

21.300-000-000. The value of any Work covered by a Change Order or of any claim for an increase or decrease in the Contract Price shall be determined in one of the following ways:

21.3.100-000-000. where the Work involved is covered by unit prices contained in the Contract Documents, by application of unit prices to the quantities of the items involved.

21.3.200-000-000. by mutual acceptance of a lump sum.

21.3.300-000-000. by cost and a mutually acceptable fixed amount for overhead and profit.

21.3.400-000-000. if none of the above methods is agreed upon, the value shall be determined by the **OWNER** on the basis of costs and a percentage for overhead and profit. Costs shall only include labor (payroll, payroll taxes, fringe benefits, workmen's compensation, etc.), materials, equipment, and other incidentals directly related to the Work involved. The maximum percentage which shall be allowed for the **CONTRACTOR'S** combined overhead and profit, shall be as follows:

21.3.4.100-000-000. for all such Work done by his own organization, the **CONTRACTOR** may add up to thirty-five percent of his actual net increase in cost, and

21.3.4.200-000-000. for all such Work done by Subcontractors, each Subcontractor may add up to fifteen percent of his actual net increase in costs for combined overhead and profit and the **CONTRACTOR** may add up to ten percent of the Subcontractor's total for his combined overhead and profit; provided that no overhead or profit shall be allowed on costs incurred in connection with premiums for public liability insurance or other special insurance directly related to such work.

In such case and also under Article 21.3.3 the **CONTRACTOR** shall submit in form prescribed by the **OWNER** an itemized cost breakdown together with supporting data.

21.400-000-000. The amount of credit to be allowed by the **CONTRACTOR** the **OWNER** for any such change which results in a net decrease in cost, shall be the amount of the actual net increase as determined by the **OWNER**. When both additions and credits are involved in any one change, the combined overhead and profit shall be figured on the basis of the net increase, if any.

21.500-000-000. In the event that a test hole or test well is called for in the contract, the **CONTRACTOR** may after completion of the test hole or test well make his own determination of whether or not the final well can be completed to the expressed intent of the Contract Documents and if desired terminate the contract and be paid for the test work as specified in the contract.

21.600-000-000. In the event that a test hole or well is not specified in the contract, the **CONTRACTOR** may at his own option and expense elect to drill a test hole or well. After completion of the test hole or well the **CONTRACTOR** may make his own determination of whether or not the contract well can be completed to the expressed intent of the Contract Documents and if he desires to terminate the contract. All information obtained from the test work shall be the property of the **CONTRACTOR**. However, the **OWNER** has the option to purchase the information for the lump sum or pro rata amount as specified for test hole/abandonment of test hole or other negotiable means.

Article 22
Cash Allowances

The **CONTRACTOR** shall include in the Contract Price all allowances so named in the Contract Documents and shall cause the Work so covered to be done by such suppliers or Subcontractors and for such sums within the limit of the allowances as the **OWNER** may approve. Upon final payment, the Contract Price shall be decreased as required and an appropriate Change Order issued. The **CONTRACTOR** agrees that the original Contract Price includes such sums as he deems proper for costs and profit on account of cash allowances. No demand for additional cost or profit in connection therewith will be allowed.

Article 23
Change of Contract Time

23.100-000-000. The Contract Time may only be changed by a Change Order. If the **CONTRACTOR** is entitled by the Contract Documents to make a claim for an extension in the Contract Time, his claim shall be in writing delivered to the **OWNER** within ten days of the occurrence of the event giving rise to the claim. All claims for adjustment in the Contract Time shall be determined by the **PROJECT REPRESENTATIVE** if the **OWNER** and the **CONTRACTOR** cannot otherwise agree. Any change in the Contract Time resulting from any such claim shall be incorporated in a Change Order.

23.200-000-000. The Contract Time shall be extended in an amount equal to time lost due to delays beyond the control of the **CONTRACTOR** if he makes a claim therefor as provided in Article 23.1. Such delays shall include, but not be restricted to, acts of neglect by any separate contractor employed by the **OWNER**, fires, floods, labor disputes, epidemics, abnormal weather conditions, or so-called *ACTS OF GOD.*

23.300-000-000. All time limits stated in the Contract Documents are of the essence of the Agreement. The provisions of this Article shall not exclude recovery for damage (including compensation for additional professional services) for delay by either party.

Article 24
Neglected Work

If the **CONTRACTOR** should neglect to prosecute the Work in accordance with the Contract Documents, including any requirements of the progress schedule, the **OWNER**, after ten day written notice to the **CONTRACTOR** may, without prejudice to any other remedy he may have, make good such deficiencies and the cost thereof (including compensation for additional professional services) shall be charged against the **CONTRACTOR** if the **OWNER** approves such action. In this event a Change Order shall be issued incorporating the necessary revisions in the Contract Documents including an appropriate reduction in the Contract Price. If the payments then or thereafter due the **CONTRACTOR** are not sufficient to cover such amount, the **CONTRACTOR** will pay the difference to the **OWNER**.

Article 25
Warranty and Guarantee; Correction
Removal or Acceptance of Defective Work

25.100-000-000. The **CONTRACTOR** warrants and guarantees to the **OWNER** that all materials and equipment shall be new unless otherwise specified and that all Work shall be of good quality and free from faults or defects and in accordance with the requirements of the Contract Documents and of any inspections, tests or approvals referred to in Article 16.2. All unsatisfactory work, all faulty or defective work and all work not conforming to the requirements of the Contract Documents or of such inspections, tests or approvals shall be considered defective. Prompt notice of all defects shall be given to the **CONTRACTOR**. All defective Work, whether or not in place, may be rejected.

~~25.200-000-000~~. If required by the **OWNER** prior to approval of final payment, the **CONTRACTOR** shall promptly, without cost to the **OWNER**, either correct any defective Work, whether or not fabricated, installed or completed, or, if the Work has been rejected by the **OWNER**, remove it from the site and replace it with nondefective work. If the **CONTRACTOR** does not correct such defective Work or remove and replace such rejected Work within a reasonable time, as required by written notice from the **PROJECT REPRESENTATIVE**, the **OWNER** may have the deficiency corrected or the rejected Work removed and replaced. All direct or indirect costs of such correction or removal and replacement, including compensation for additional professional services shall be paid by the **CONTRACTOR**, and an appropriate Change Order shall be issued deducting all such costs from the Contract Price. The **CONTRACTOR** shall also bear the expense of making good all work of others destroyed or damaged by his correction, removal or replacement of his defective Work.

~~25.300-000-000~~. If, after the approval of final payment and prior to the expiration of one year after the date of Substantial Completion or such longer period of time as may be prescribed by law or by the terms of any applicable special guarantee required by the Contract Documents, any Work is found to be defective, the **CONTRACTOR** shall, promptly and without cost to the **OWNER**, and in accordance with the **OWNER'S** written instructions, either correct such defective Work, or, if it has been rejected by the **OWNER**, remove it from site and replace it with nondefective Work. If the **CONTRACTOR** does not promptly comply with the terms of such instructions, the **OWNER** may have the defective Work corrected or the rejected work removed and replaced, and all direct and indirect costs of such removal and replacement, including compensation for additional professional services, shall be paid by the **CONTRACTOR**.

~~25.400-000-000~~. If, instead of requiring correction or removal and replacement of defective Work, the **OWNER** prefers to accept it, he may do so. If such acceptance occurs prior to approval of final payment, a Change Order shall be issued incorporating the necessary revisions in the Contract Documents, including appropriate reduction in the Contract Price; or, if the acceptance occurs after approval of final payment, an appropriate amount shall be paid by the **CONTRACTOR**.

Article 26
Application for Progress Payments

~~26.100-000-000~~. At least ten days prior to submitting the first Application for a progress payment, the **CONTRACTOR** shall submit a schedule of values of the Work including quantities and unit prices aggregating the Contract Price. This schedule shall be satisfactory in form and substance to the **OWNER** and shall subdivide the Work into component parts in sufficient detail to serve as the basis for progress payments during construction. Upon approval of the schedule of values by the **OWNER** it shall be incorporated into thq form of an Application for Payment furnished by the **OWNER**.

26.200-000-000. At least ten days before each progress payment falls due (but not more often than once a month), the **CONTRACTOR** shall submit to the **OWNER** for review the Application for Payment filled out and signed by the **CONTRACTOR** covering the Work completed as of the date of the Application and supported by such data as the **OWNER** may reasonably require. If payment is requested on the basis of materials and equipment not incorporated in the Work but delivered and suitably stored at the site or at another location agreed to in writing, the Application for Payment shall also be accompanied by such supporting data, satisfactory to the **OWNER**, as will establish the **OWNER'S** title to the material and equipment and protect his interests therein, including applicable insurance.

26.300-000-000. The **CONTRACTOR** warrants and guarantees that title to all Work, materials and equipment covered by an Application for Payment, whether incorporated in the Project or not, shall have passed to the **OWNER** prior to the making of the Application for Payment, free and clear of all liens, claims, security interests and encumbrances (thereafter in the General Conditions referred to as "Liens"); and that no Work, materials or equipment covered by an Application for Payment shall have been acquired by the **CONTRACTOR** or any other person performing the Work at the site or furnishing materials and equipment for the Project, subject to an agreement under which an interest therein or encumbrance thereon is retained by the seller or otherwise imposed by the **CONTRACTOR** or such other person.

26.400-000-000. The **PROJECT REPRESENTATIVE** shall, within ten days after receipt of each Application for Payment, either indicate in writing his approval of payment and present the Application to the **OWNER**, or return the Application to the **CONTRACTOR** indicating in writing his reasons for refusing to approve payment. In the latter case, the **CONTRACTOR** may make the necessary corrections and resubmit the Application. The **OWNER** will, within ten days of presentation to him of an approved Application for Payment, pay the **CONTRACTOR** the amount approved by the **PROJECT REPRESENTATIVE**.

Article 27
Approval of Payments

27.100-000-000. The **PROJECT REPRESENTATIVE'S** approval of any payment requested in Application for Payment shall constitute a representation by him to the **OWNER**, based on the **PROJECT REPRESENTATIVE'S** on-site observations of the Work in progress as an experienced and qualified design professional and on his review of the Application for Payment and the supporting data, that the Work has progressed to the point indicated; that, to the best of his knowledge, information and belief, the quality of the Work is in accordance with the Contract Documents (subject to an evaluation of the Work as a functioning Project upon Substantial Completion, and to the results of any subsequent tests called for in the Contract Documents and any qualifications stated in his approval); and that the **CONTRACTOR** is entitled to payment of the amount approved. However, by approving any such payment the **PROJECT REPRESENTATIVE** shall not thereby be deemed to have represented that he made exhaustive or continuous on-site inspections to check the quality or the quantity of the Work, or that he has reviewed the means, methods, techniques, sequences, and procedures of construction or that he has made any examination to ascertain how or for what purpose the **CONTRACTOR** has used the moneys paid or to be paid to him on account of the Contract Price.

27.200-000-000. The **PROJECT REPRESENTATIVE'S** approval of final payment shall constitute an additional representation by him to the **OWNER** that the conditions precedent to the **CONTRACTOR'S** being entitled to final payment as set forth in Article 30.3 have been fulfilled.

27.300-000-000. The **PROJECT REPRESENTATIVE** may refuse to approve the whole or any part of any payment if, in his opinion, he is unable to make such representations to the **OWNER**. He may also refuse to approve any such payment, or, because of subsequently discovered evidence or the results of subsequent inspection or tests, nullify any such payment previously approved, to such extent as may be necessary in his opinion to protect the **OWNER** from loss because:

27.3.100-000-000. the Work is defective,

27.3.200-000-000. claims have been filed or there is reasonable evidence indicating the probable filing thereof,

27.3.300-000-000. the Contract Price has been reduced because of Modifications,

27.3.400-000-000. the **OWNER** has been required to correct defective Work in accordance with Article 24, or

27.3.500-000-000. unsatisfactory prosecution of the Work, including failure to clean up as required by Article 37.

Article 28
Substantial Completion

28.100-000-000. Prior to final payment, the **CONTRACTOR** may, in writing to the **OWNER**, certify that the entire Project is substantially complete and request that the **OWNER** or his agent issue a certificate of Substantial Completion. Within a reasonable time thereafter, the **OWNER** and **CONTRACTOR** will make an inspection of the Project to determine the status of completion. If the **OWNER** or his agent does not consider the Project substantially complete, he shall notify the **CONTRACTOR** in writing giving his reasons therefor. If the **OWNER** or his agent considers the Project substantially complete, he shall prepare and deliver to the **CONTRACTOR** a tentative certificate of Substantial Completion which shall fix the date of Substantial Completion and the responsibilities between the **OWNER** and the **CONTRACTOR** for maintenance, heat and utilities. There shall be attached to the certificate a tentative list of items to be completed or corrected before final payment, and the certificate shall fix the time within which such items shall be completed or corrected, said time to be within the Contract Time. The **CONTRACTOR** shall have seven days after receipt of the tentative certificate during which he may make written objection to the **PROJECT REPRESENTATIVE** as to any provisions of the certificate or attached list. If, after considering such objections, the **OWNER** concludes that the Project is not substantially complete, he may notify the **CONTRACTOR** in writing, stating his reasons therefor. If, after seven days and after consideration of the **OWNER'S** objections, the **PROJECT REPRESENTATIVE** considers the Project substantially complete, he shall execute and deliver to the **OWNER** and the **CONTRACTOR** a tentative certificate of Substantial Completion (with a revised list of items to be completed or corrected) reflecting such changes from the tentative certificate as he believes justified after consideration of any objections from the **OWNER**.

28.200-000-000. The **OWNER** shall have the right to exclude the **CONTRACTOR** from the Project after the date of Substantial Completion, but the **OWNER** shall allow the **CONTRACTOR** reasonable access to complete or correct items on the tentative list.

Article 29
Partial Utilization

Prior to final payment, the **OWNER** may request the **CONTRACTOR** in writing to permit him to use a specified part of the Project which he believes he may use without significant interference with construction of the other parts of the Project. If the **CONTRACTOR** agrees, he shall certify to the **OWNER** that said part of the Project is substantially complete and request the **OWNER** or his agent to issue a certificate of Substantial Completion for that part of the Project. Within a reasonable time thereafter the **OWNER** and **CONTRACTOR** shall make an inspection of that part of the Project to determine its status of completion. If the **PROJECT REPRESENTATIVE** does not consider that it is substantially complete, he shall notify the **OWNER** and **CONTRACTOR** in writing giving his reasons therefor. If the **PROJECT REPRESENTATIVE** considers that part of the Project to be substantially complete, he shall execute and deliver to the **OWNER** and **CONTRACTOR** a certificate to that effect, fixing the date of Substantial Completion as to that part of the Project, attaching thereto a tentative list of items to be completed or corrected before final payment and fixing the responsibility between the OWNER and CONTRACTOR for maintenance, heat and utilities as to that part of the Project. The OWNER shall have the right to exclude the CONTRACTOR from any part of the Project which the PROJECT REPRESENTATIVE has so certified to be substantially complete, but the OWNER shall allow the CONTRACTOR reasonable access to complete or correct items on the tentative list.

Article 30
Final Payment

30.100-000-000. Upon written notice from the CONTRACTOR that the Project is complete, the OWNER or his agent shall make a final inspection with the CONTRACTOR, and the OWNER will notify the CONTRACTOR in writing of any particulars in which this inspection reveals that the Work is defective. The CONTRACTOR shall immediately make such corrections as are necessary to remedy such defects.

30.200-000-000. After the CONTRACTOR has completed any such corrections to the satisfaction of the OWNER and delivered all maintenance and operating instructions, schedules, guarantees, bonds, certificates of inspection and other documents—all as required by the Contract Documents, he may make application for final payment following the procedure for progress payments. The final Application for Payment shall be accompanied by such supporting data as the PROJECT REPRESENTATIVE may require, together with complete and legally effective releases or waivers (satisfactory to the OWNER) of all Liens arising out of the Contract Documents and the labor and services performed and the material and equipment furnished thereunder. In lieu thereof and as approved by the OWNER, the CONTRACTOR may furnish receipts or releases in full; an affidavit of the CONTRACTOR that the release and receipts include all labor, services, material and equipment for which a lien could be filed, and that all payrolls, material and equipment bills, and other indebtedness connected with the Work for which the OWNER or his property might in any way be responsible, have been paid or otherwise satisfied; and consent of the surety, if any, to final payment. If any Subcontractor or supplier fails to furnish a release or receipt in full, the CONTRACTOR may furnish a bond satisfactory to the OWNER to indemnify him against any Lien.

30.300-000-000. On the basis of his observation and review of the Work during construction, his final inspection and his review of the final Application for Payment—all as required by the Contract Documents, the PROJECT REPRESENTATIVE shall, within ten days after receipt of the final Application for Payment, indicate in writing his approval of payment and present the Application to the OWNER for payment. Otherwise, he shall return the Application to the CONTRACTOR, indicating in writing his reasons for refusing to approve the final payment, in which case the

CONTRACTOR shall make the necessary corrections and resubmit the Application. The **OWNER** shall, within ten days of presentation to him of an approved final Application for Payment, pay the **CONTRACTOR** the amount approved by the **PROJECT REPRESENTATIVE.**

30.400-000-000. If after Substantial Completion of the Work, final completion thereof is materially delayed through no fault of the **CONTRACTOR**, and the **PROJECT REPRESENTATIVE** so confirms, the **OWNER** shall, upon certification by the **PROJECT REPRESENTATIVE**, and without terminating the Agreement, make payment of the balance due for the portion of the Work fully completed and accepted. If the remaining balance for Work not fully completed or corrected is less than the retainage stipulated in the Agreement, and if Bonds have been furnished as required in Article 33, the written consent of the surety to the payment of the balance due for that portion of the Work fully completed and accepted shall be submitted by the **CONTRACTOR** to the **PROJECT REPRESENTATIVE** prior to certification of such payment. Such payment shall be made under the terms and conditions governing final payment, except that it shall not constitute a waiver of claims.

Article 31
Waivers of Claims and Continuing Obligations

31.100-000-000. The **CONTRACTOR'S** obligation to perform the Work and complete the Project in accordance with the Contract Documents shall be absolute. Neither approval of any progress or final payment by the **PROJECT REPRESENTATIVE**, nor the issuance of certificate of Substantial Completion, nor any payment by the **OWNER** to the **CONTRACTOR** under the Contract Documents, nor any use or occupancy of the Project or any part thereof by the **OWNER**, nor any act of acceptance by the **OWNER** nor any failure to do so, nor any correction of faulty or defective work by the **OWNER** shall constitute an acceptance of Work not in accordance with the Contract Documents.

31.200-000-000. The making and acceptance of final payment shall constitute:

31.2.100-000. a waiver of all claims by the **OWNER** against the **CONTRACTOR** other than those arising from unsettled Liens, from faulty or defective work appearing after final payment, or from failure to comply with the requirements of the Contract Documents, or the terms of any special guarantees specified therein, and

31.2.200-000. a waiver of all claims by the **CONTRACTOR** against the **OWNER** other than those previously made in writing and still unsettled.

Article 32
Indemnification

32.100-000-000. The **CONTRACTOR** shall indemnify and hold harmless the **OWNER** and the **PROJECT REPRESENTATIVE** and their agents and employees from and against all claims, damages, losses and expenses including attorneys' fees arising out of or resulting from the performance of the Work, provided that any such claim, damage, loss or expense (a) is attributable to bodily injury, sickness, disease or death, or to injury to or destruction of tangible property (other than the Work itself) including the loss of use resulting therefrom and (b) is caused in whole or in part by any negligent act or omission of the CONTRACTOR, any Subcontractor, anyone directly or indirectly employed by any of them or anyone for whose acts any of them may be liable, regardless of whether or not it is caused in part by a party indemnified hereunder.

32.200-000-000. In any and all claims against the OWNER or any of his agents or employees by any employee of the CONTRACTOR, any Subcontractor, anyone directly or indirectly employed by any of them or anyone for whose acts any of them may be liable, the indemnification obligation under this Article 32 shall not be limited in any way by any limitation on the amount or type of damages, compensation or benefits payable by or for the CONTRACTOR or any Subcontractor under workmen's compensation acts, disability benefit acts or other employee benefit acts.

32.700-000-000. The obligations of the CONTRACTOR under Article 32 shall not extend to the liability of the PROJECT REPRESENTATIVE, his agents or employees arising out of (a) the preparation or approval of maps, drawings, opinions, reports, surveys, Change Orders, designs or specifications or (b) the giving of or the failing to give directions or instructions by the PROJECT REPRESENTATIVE, his agents or employees provided such giving or failing to give is the primary cause of injury or damage.

Article 33
Contract Bonds

The CONTRACTOR shall furnish performance and payment Bonds as security for the faithful performance and payment of all his obligations under the Contract Documents. These Bonds shall be in amounts at least equal to the Contract Price and in such form and with such sureties as are acceptable to the OWNER. Prior to execution of the Contract Documents the OWNER may require the CONTRACTOR to furnish such other Bonds, in such form and with such sureties as he may require. If such Bonds are required by written instructions given prior to opening of Bids, the premiums shall be paid by the CONTRACTOR; if subsequent thereto, they shall be paid by the OWNER.

Article 34
CONTRACTOR'S *Liability Insurance*

The CONTRACTOR shall purchase and maintain such insurance as will protect him from claims under workmen's compensation laws, disability benefit laws or other similar employee benefit laws; from claims for damages because of bodily injury, occupational sickness or disease, or death of his employees, and claims insured by usual personal injury liability coverage; from claims for damages because of bodily injury, sickness or disease, or death of any person other than his employees including claims insured by usual personal injury liability coverage; and from claims for injury to or destruction of tangible property, including loss of use resulting therefrom, any or all of which may arise out of or result from the CONTRACTOR'S operations under the Contract Documents, whether such operations be by himself or by any Subcontractor or anyone directly or indirectly employed by any of them or from whose acts any of them may be legally liable. This insurance shall be written for not less than the limits of liability specified in the Contract Documents or required by law, whichever is greater, and shall include contractual liability insurance. Before starting the Work, the CONTRACTOR shall file with the OWNER certificates of such insurance, acceptable to the OWNER; these certificates shall contain a provision that the coverage afforded under the policies will not be cancelled or materially changed until at least fifteen days prior written notice has been given the OWNER.

Article 35
OWNER'S *Liability Insurance*

The OWNER shall be responsible for purchasing and maintaining his own liability insurance and, at his option, may purchase and maintain such insurance as will protect him against claims which may arise from operations under the Contract Documents.

Article 36
Property Insurance

36.100-000-000. Unless otherwise provided, the OWNER shall purchase and maintain property insurance on the Project to the full insurable value thereof. This insurance shall include the interests of the OWNER, the CONTRACTOR and Subcontractors in the Work and shall insure against the perils of Fire, Extended Coverage, Vandalism and Malicious Mischief.

36.200-000-000. The OWNER shall purchase and maintain such steam boiler and machinery insurance as may be required by the Contract Documents or by law. This insurance shall include the interests of the OWNER, the CONTRACTOR and Subcontractors in the Work.

36.300-000-000. Any insured loss under the policies of insurance required by Articles 36.1 and 36.2 is to be adjusted with the OWNER and made payable to the OWNER as trustee for the insurers, as their interests may appear, subject to the requirements of any applicable mortgage clause and of Article 36.7.

56.400-000-000. The OWNER shall file a copy of all policies with the CONTRACTOR before an exposure to loss may occur. If the OWNER does not intend to purchase such insurance, he shall inform the CONTRACTOR in writing prior to commencement of the Work. The CONTRACTOR may then effect insurance which will protect the interests of himself and his Subcontractors in the Work, and by appropriate Change Order the cost thereof shall be charged to the OWNER. If the CONTRACTOR is damaged by failure of the OWNER to purchase or maintain such insurance and so to notify the CONTRACTOR, then the OWNER shall bear all reasonable costs properly attributable thereto.

56.500-000-000. If the CONTRACTOR requests in writing that other special insurance be included in the property insurance policy, the OWNER will, if possible, include such insurance, and the cost thereof shall be charged to the CONTRACTOR by appropriate Change Order.

56.600-000-000. The OWNER and CONTRACTOR waive all rights against each other for damages caused by fire or other perils to the extent covered by insurance provided under this Article, except such rights as they may have to the proceeds of such insurance held by the OWNER as trustee. The CONTRACTOR shall require similar waivers by Subcontractors in accordance with Article 7.7.

56.700-000-000. The OWNER as trustee shall have power to adjust and settle any loss with the insurers unless one of the parties in interest shall object in writing within five days after the occurrence of loss to the OWNER'S exercise of this power, and if such objection be made, arbitrators shall be chosen as provided in Article 41. The OWNER as trustee shall, in that case, make settlement with the insurers in accordance with the directions of such arbitrators. If distribution of the insurance proceeds by arbitration is required, the arbitrators will direct such distribution.

Article 57
Cleaning Up

The CONTRACTOR shall keep the premises free from accumulations of waste materials, rubbish and other debris resulting from the Work, and at the completion of the Work, he shall remove all waste materials, rubbish and debris from and about the premises as well as all tools, construction equipment and machinery, and surplus materials, and leave the site clean and ready for occupancy by the OWNER. The CONTRACTOR shall restore to their original condition those portions of the site not designated for alteration by the Contract Documents.

Article 58
OWNER'S *Right to Stop or Suspend Work*

58.100-000-000. If the Work is defective, or the CONTRACTOR fails to supply sufficient skilled workmen or suitable materials or equipment, or if the **CONTRACTOR** fails to make prompt payments to Subcontractors or for labor, materials or equipment, the **OWNER** may order the **CONTRACTOR** to stop the Work, or any portion thereof, until the cause for such order has been eliminated.

38.200-000-000. The **OWNER**, may, at any time and without cause, suspend the Work or any portion thereof for a period of not more than ninety days by notice in writing to the **CONTRACTOR** and the **PROJECT REPRESENTATIVE** which shall fix the date on which Work shall be resumed. The **CONTRACTOR** shall resume the Work on the date so fixed. The **CONTRACTOR** shall be allowed an increase in the Contract Price or an extension of the Contract Time directly attributable to any suspension if he makes a claim therefor as provided in Articles 21 and 23.

Article 39
OWNER'S *Right to Terminate*

39.100-000-000. If the **CONTRACTOR** is adjudged bankrupt or insolvent, or if he makes a general assignment for the benefit of his creditors without the approval of the **OWNER**, or if a trustee or receiver is appointed for the **CONTRACTOR** or for any of his property, or if he files a petition to take advantage of any debtors' act, or to reorganize under the bankruptcy or similar laws, or if he repeatedly fails to supply sufficient skilled workmen or suitable materials or equipment, or if he repeatedly fails to make prompt payments to Subcontractors or for labor, materials or equipment or if he disregards laws, ordinances, rules, regulations or orders of any public body having jurisdiction, or if he disregards the authority of the **PROJECT REPRESENTATIVE**, or if he otherwise violates any provision of the Contract Documents, then the **OWNER** may, without prejudice to any other right or remedy and after giving the **CONTRACTOR** and his surety ten days from the receipt of the written notice, terminate the services of the **CONTRACTOR** and take possession of the Project and of all materials to be incorporated therein, and finish the Work by whatever method he may deem expedient. In such case the **CONTRACTOR** shall not be entitled to receive any further payment until the Work is finished. If the unpaid balance of the Contract Price exceeds the direct and indirect costs of completing the Project, including compensation for additional professional services, such excess shall be paid to the **CONTRACTOR**. If such costs exceed such unpaid balance, the **CONTRACTOR** shall pay the difference to the **OWNER**. Such costs incurred by the **OWNER** shall be determined by the **PROJECT REPRESENTATIVE** and incorporated in a Change Order.

39.200-000-000. Where the **CONTRACTOR'S** services have been so terminated by the **OWNER**, said termination shall not affect any rights of the **OWNER** against the **CONTRACTOR** nor any rights of the **CONTRACTOR** against the **OWNER**, then existing or which may thereafter accrue.

Any retention or payment of moneys by the **OWNER** due the **CONTRACTOR** shall not release the **CONTRACTOR** from liability.

39.200-000-000. Upon seven day written notice to the **CONTRACTOR** and the **PROJECT REPRESENTATIVE**, the **OWNER** may, without cause and without prejudice to any right or remedy, elect to abandon the Project and terminate the Agreement. In such case, the **CONTRACTOR** shall be paid for all Work executed and any expense sustained plus a reasonable profit.

Article 40
CONTRACTOR'S *Right to Stop Work or Terminate*

If, through no act or fault of the **CONTRACTOR**, the Work is suspended for a period of more than ninety days by the **OWNER** or under an order of court or other public authority, or the **PROJECT REPRESENTATIVE** fails to act on any Application for Payment within thirty days after it is submitted, or if the **OWNER** fails to pay the **CONTRACTOR** any sum approved by the **PROJECT REPRESENTATIVE** or awarded by arbitrators within thirty days of its approval and presentation, then the **CONTRACTOR** may, upon seven day written notice to the **OWNER**, terminate the Agreement and recover from the **OWNER** payment for all Work executed and any expense sustained plus a reasonable profit. In addition and in lieu of terminating the Agreement, if the **PROJECT REPRESENTATIVE** has failed to act on an Application for Payment or if the **OWNER** has failed to make any payment as aforesaid, the **CONTRACTOR** may upon seven days notice to the **OWNER** stop the Work until he has been paid all amounts then due. In this event the **CONTRACTOR** shall be entitled to an Extra Work Order for his direct costs incurred during the shutdown, plus ten percent.

Article 41
Arbitration

41.100-000-000. All claims, disputes and other matters in question arising out of, or relating to, this Agreement or the breach thereof except for claims which have been waived by the making or acceptance of final payment as provided by Article 31.2, shall be decided by arbitration in accordance with the Construction Industry Arbitration Rules of the American Arbitration Association. This agreement to so arbitrate shall be specifically enforceable under the prevailing arbitration law. The award rendered by the arbitrators shall be final, and judgment may be entered upon it in any court having jurisdiction thereof.

41.200-000-000. Notice of the demand for arbitration shall be filed in writing with the other party to the Agreement and with the American Arbitration Association, and a copy shall be filed with the **OWNER**. The demand for arbitration shall be made within the thirty day period specified in Article 14.3 where applicable, and in all other cases within a reasonable time after the claim, dispute or other matter in question has arisen, and in no event shall it be made after institution of legal or equitable proceedings based on such claim, dispute or other matter in question, which would be barred by the applicable statute of limitations.

41.300-000-000. The CONTRACTOR shall carry on the Work and maintain the progress schedule during any arbitration proceedings, unless otherwise agreed by him and the OWNER in writing.

Article 42
Miscellaneous

42.100-000-000. Whenever any provision of the Contract Documents requires the giving of written notice it shall be deemed to have been validly given if delivered in person to the individual or to a member of the firm or to an officer of the corporation for whom it is intended, or if sent by registered or certified mail, postage prepaid, to the business address used in the advertisement for bids or in the contract documents.

42.200-000-000. All moneys not paid when due hereunder shall bear interest at the legal rate in force at the place of the Project.

42.300-000-000. The duties and obligations imposed by these General Conditions and the rights and remedies available hereunder, and, in particular but without limitation, the warranties, guarantees and obligations imposed upon the CONTRACTOR by Articles 25 and 32 and the rights and remedies available to the OWNER thereunder, shall be in addition to and not a limitation of any otherwise imposed or available by law, by special guarantee or other provisions of the Contract Documents.

42.400-000-000. Should the OWNER or the CONTRACTOR suffer injury or damage to his person or property because of any error, omission or act of the other or of any of his employees or agents or others for whose acts he is legally liable, claim shall be made in writing to the other party within a reasonable time of the first observance of such injury or damage.

42.500-000-000. The Contract Documents shall be governed by the law of the place of the Project.

42.600-000-000. The full responsibility for design shall be borne by the OWNER unless specific design responsibility is given to the CONTRACTOR elsewhere in the Contract Documents.

Section 8

Special Conditions

Article 43
General

The Special Conditions shall supplement and modify the General Conditions and shall govern in the event of conflicts or contradictions between them and the General Conditions. Commentary: Special Conditions must be written individually for each project. Items often considered under Special Conditions are listed below. Every effort should be made to maintain consistency between the Special Conditions and General Conditions, but it is recognized that variations will occur:

A. Scope and General Description of Work to Include Test Hole Size, Well Size, Depth and Whether it is the Intent to Either Obtain the Maximum Available Production Rate or a Designated Production Rate, if Indicated Here: ____________________
B. Sub-Surface Information
C. Work Schedule
D. Liquidated Damages
E. Special Permits, Taxes, Legal Easements, Property Boundaries, etc.
F. Location of Existing Utilities
G. Availability of Construction Utilities
H. Specific Insurance Requirements
I. Bond Requirements
J. Submittals
K. Field Office
L. Material Variations
M. Owner's Right to Purchase Test Well
N. Time and Notice of All Tests
O. Material Selection for Casing and Screens (Metallic or Non-metallic)

Article 44
Glossary of Technical Terms

PREAMBLE

Incorporated into these standards are definitions of selected terms.

Abandoned Well. A well whose original purpose and use have been permanently discontinued or which is in such a state of disrepair that its original purpose cannot be reasonably achieved.

Absorption. The penetration of molecules or ions of one substance into the interior of a solid or liquid.

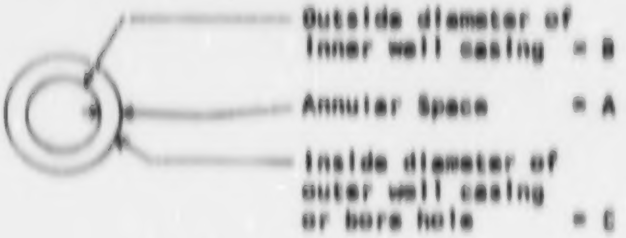
Acidizing. The process of introducing acid into an acid-soluble formation for the purpose of enlarging the pore space by dissolving the surrounding formation. Acidizing also refers to the removal of encrustants from well screen and gravel pack, and dissolving cemented materials.

Adsorption. Attachment on the surfaces of solids of gases, liquids or dissolved substances with which they are in contact.

Air Line. The smaller vertical air pipe usually extending from the surface submerged to within a few feet of the bottom of the eductor pipe. The length of the air line below the static water level is used in calculating the air pressure required to start the air-lift.

Anion. A negatively charged ion or radical.

Annular Space (A).



$$A = \frac{C-B}{2}$$

Apparent Specific Gravity. The ratio of the weight of a given volume of dry soil to an equal volume of water under standard conditions.

Aquiclude. A porous formation capable of absorbing water but which will not transmit it fast enough to supply a well.

Aquifer. A geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian Well. A well in an aquifer where the ground water is confined under pressure and the water level stands above the top of the confined water body it taps.

Bailer. A long narrow bucket made of pipe with a valve in the bottom used to remove cuttings from the hole.

Bailer (piston tube). A type of bailer (or sampler) that is fitted with a of pipe with a flat bottom check valve for removing earth materials from the bottom of hole; usually employed with the cable tool method.

Bailer (flat bottom). A type of Bailer (or sampler) that has a length plunger so that an upward pull on the plunger produces a partial vacuum that opens a valve and sucks sand or slurried cuttings into the bailer tube.

Bentonite. A highly plastic, colloidal clay composed largely of mineral montmorillonite.

Bradenhead. A pack-off or seal between two casings.

Cake Thickness. The thickness of filter cake deposited against porous media by the drilling fluid.

Capillarity. The property of tubes with minute openings which, when immersed in a fluid, raise or depresses the fluid in the tubes above or below the surface of the fluid in which they are immersed.

Capillary Fringe. The zone immediately above the water table in which water is held by capillarity.

Casing. A tubular retaining structure, generally metal, which is installed in the excavated hole to maintain the well opening.

Centralizer. Used to center casing in the hole, insuring uniform annular space for effective grouting.

Cementing (positive emplacement). A technique of installation of cementing materials whereby emplacement is achieved by positive pressure extended from the bottom of the zone upward via a grout pipe extending from the surface.

Clay. A fine-grained inorganic material (grains less than 0.0005 mm in diameter) which has very low permeability and is plastic.

Coefficient of Transmissibility. The field coefficient of permeability multiplied by the aquifer thickness in feet. The terms has been replaced by "transmissivity".

Coefficient of Viscosity. The force required to maintain a unit difference in velocity between two layers of water a unit distance apart.

Conductor Pipe or Casing. A tubular retaining structure installed between the drilled hole and the inner casing, in the upper portion of a well.

Cone of Pressure Relief. An imaginary conical surface of the water level indicating pressure relief in a confined aquifer due to pumping.

Cone of Depression. The conical surface of the water level created in an unconfined aquifer due to pumping.

Confined Ground Water. Ground water under pressure significantly greater than atmospheric pressure; and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

Core (side hole). A sampling device that scrapes the side of existing hole via a pneumatically operated coring blade removing formation material as the device is raised up the sampling interval desired. The sample passes the bladed coring bit and falls into a bag within the core barrel.

Core Bailer. A length of pipe used as a coring device for retrieval of earth materials from the bottom of the hole. Usually has a spring loaded "core catcher" at bottom to retain material in core barrel.

Curing Time. Minimum time required for particular types of cementing or grouting materials to harden (or set up) before drilling or other construction operations can be resumed.

Deep Well. The term "deep" has no real significance relative to the actual depth of a well. Such usage is eliminated from technical and legal applications in favor of specific depths.

Domestic Water Supply. One family water supply.

Drawdown. The difference in levels between the static water level and the surface of the cone of depression.

Drilled Well. A well for which the hole is generally excavated by mechanical means such as the rotary or cable tool methods.

Drilling Mud. A fluid composed of water and bentonite used in the drilling (primarily rotary) operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill stem and the sides of the hole, and to plaster the sides of the hole. Such fluids range from relatively clear water to carefully prepared mixtures of special purpose compounds.

Drive Shoe. A forged steel collar with a cutting edge fastened onto the bottom of casing to shear off irregularities in the hole as the casing advances, and to protect the lower edge of the casing as it is driven.

Eductor. The vertical discharge pipe, usually submerged about two-thirds of its length below the pumping water level in the well.

Electrolyte. A chemical which dissociates into positive and negative ions when dissolved in water, increasing the electrical conductivity.

Filter Loss. The amount of fluid delivered through a permeable membrane in a specified time.

Filtration Rate. Water loss per unit time.

Gel. A colloidal suspension in which shearing stresses below a certain value fail to produce permanent deformation.

Gel-Strength. A measure of the ability of colloids to form gels.

Geophysical/Mechanical Logging. Geophysical logging is composed of a number of techniques that measure some electrical, chemical or radioactive property of the subsurface, either characteristic of the ground water or of the rocks in which the ground water occurs. Typical techniques include: Resistivity and Self-Potential Logging (called Electric Logging,) Gamma and Neutron Logging (called Radiation Logging), etc. Mechanical

Logging incorporates mechanical devices, as opposed to electronic or electric, that measure some physical property of the subsurface, e.g., Caliper Logging, Temperature Logging, Photographic Logging, etc. The following apply for any and all geophysical/mechanical logs specified in these Standards (See Article 45, Preamble).

Gravel Packed Well. A well in which filter material is placed in the annular space to increase the effective diameter of the well, and to prevent fine-grained sediments from entering the well.

Ground Water. Water in the zone of saturation.

Ground Water Divide. A line on a water table on each side of which the water table slopes downward in a direction away from the line.

Ground Water Mound. A mound-shaped addition to the ground water body built up by seepage, percolation, or recharge.

Ground Water Ridge. A ridge-shaped addition to the ground water body such as may be built up by an influent stream.

Grout. A fluid mixture of cement and water (neat cement) of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, are included in the mixture to meet certain requirements. For example, sand is added when a considerable volume of grout is needed.

Heat of Hydration. The heat evolved during the setting and hardening of portland cement.

Homogeneous. Material of essentially uniform characteristics of composition, texture, appearance, etc.

Hydraulic Gradient. The change in static head per unit of distance in a given direction. If not specified the direction generally is understood to be that of the maximum rate of decrease in head.

Hydrologic Properties. The properties of rocks which control the entrance of water, and the capacity to hold and transmit water.

Laminar Flow. Movement of fluid particles in essentially parallel paths.

Lift. The vertical distance from the pumping level to the point of discharge of the water plus the friction loss in the eductor pipe.

Logging. (For Type of See "Geophysical/Mechanical Logging.")

Mechanical Logging. (See "Geophysical/Mechanical Logging.")

Nonhomogeneous. Material of essentially non-uniform characteristics of composition, texture, appearance, etc.

Packer. A device placed in a well which plugs or seals the well at a specific point.

Perched Ground Water. Ground water in a saturated zone which is separated from the main body of ground water by unsaturated rock.

Perforations. A series of openings in a well casing, made either before or after installation of the casing, to permit the entrance of water into the well.

Permeability. A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient. It is a property of the medium alone and is independent of the nature of the liquid and of the force field causing movement. It is a property of the medium that is dependent upon the shape and size of the pores.

Telescoping. A method of fitting or placing one casing inside another, or of introducing screen through a casing diameter larger than the diameter of the screen.

Test Hole. Hole designed to obtain information on ground water quality and/or geological and hydrological conditions.

Test Well. Well completed for pumping.

Thixotropy. The property of some gels repeatedly to become liquid on agitation and gelling again at rest.

Transmissivity. The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

Tremie Pipe. A device, usually a small diameter pipe, that carries grouting materials to the bottom of the hole and which allows pressure grouting from the bottom up without introduction of appreciable air pockets.

Uniformity Coefficient. The uniformity coefficient is a ratio of the sieve size that will retain 40 percent of the aquifer materials to the effective size. The sieve size that retains 90 percent of the aquifer materials is the effective size.

Water-Cement Ratio. The amount of mixing water in gallons used per sack of cement.

Water Table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by the levels at which water stands in wells that penetrate the water body just far enough to hold standing water.

Well Log. *(See "Geophysical/Mechanical Logging.")*

Well Point. A short length of well screen attached to the lower end of the pipe installed by driving via repeated blows to the desired position in an aquifer or in a formation to be dewatered. A forged steel point is usually attached to the lower end of the screen to facilitate penetration.

Well Screen. Serves as the intake section of the well that obtains water from an aquifer of unconsolidated materials such as sand. It allows water to flow freely into the well from water saturated sand, prevents sand from entering with the water, and serves as a structural retainer to support the bore hole in unconsolidated material. Numerous types are available and their application depends on the specific hydrogeologic conditions present.

Zone of Aeration. The zone above the water table in which the interstices are partly filled with air. The term is replaced by "unsaturated zone". It includes the capillary fringe.

Zone of Saturation. The zone below the water table in which all interstices are filled with ground water.

Section 3

Technical Standards

Article 45
Test Holes and Samples

Preamble

The purpose of drilling a test hole is to obtain information on ground-water quality and formation materials, and to help establish the depth and extent of the water-bearing formation or formations at a specified site. Frequently the test hole will be enlarged and cased, becoming the finished well. This is true with nearly every well constructed by the rotary method wherein the "pilot hole" is, in effect, a test hole.

When warranted a test hole may be converted into a test *well* fully capable of being operated as a permanent production well.

It is recommended that samples be collected of all materials penetrated by the drilled well. As many samples should be taken as required and by such means as will assure collection of representative samples of a specific aquifer(s), or formation(s) that will be free of material from intervals above the aquifer or formation of interest. The sample may be obtained with a bailer screw, or by coring or other means, such as return flow sampling. Care must be taken to accurately determine the depth interval from which each sample is taken.

After final depth is reached, a geophysical log may be required. The logging shall be done by a logging service or by competent personnel provided by the CONTRACTOR and approved by the OWNER or his representative.

Geophysical logging would include all techniques of lowering sensing devices into a borehole and recording some physical parameter that may be interpreted in terms of the characteristics of the rocks, the fluids contained in the rocks, or the construction of the well. It should be the CONTRACTOR'S responsibility to conduct any geophysical logging operation called for in the specifications or to arrange for it unless otherwise directed by the OWNER or his authorized agent. The interval to be logged should be the total depth of the borehole subject to satisfactory borehole conditions, the limitations of the logging technique, and/or other directives from the OWNER or his authorized agent.

Borehole Preparation. When the hole has been drilled to a depth determined by contractual and/or geological conditions it must be prepared for geophysical logging. Borehole preparation shall include, but not be limited to: (1) continuation of circulation until drill cuttings have been removed from the borehole and (2) circulation of the drilling mud in the borehole until it is uniform and the drill pipe has been removed from the borehole. The CONTRACTOR must make all reasonable efforts to leave the borehole free from obstructions in preparation for geophysical logging. The log(s) must be made immediately following the completion of borehole preparation unless otherwise stated in the contract or so stipulated by the OWNER or his authorized agent.

Borehole Logging Equipment. If the CONTRACTOR conducts the operation, it must be his responsibility, unless otherwise stated in the contract or directed by the OWNER, to assure that geophysical/well logging instruments and equipment used to make the proper log must be in good condition so as to give an accurate and representative log. It must also be the responsibility of the CONTRACTOR to: (1) select vertical scale units for the log commensurate with the purpose of the log, (2) see that all logs are recorded at the highest sensitivity that is consistent with a minimum of off-scale deflection, and (3) see that scales, calibration and standardization, and other pertinent data are recorded on each log.

If the operation is conducted by a commercial logging service, the above responsibilities are delegated to that logging service.

Geophysical Log Interpretations. Geophysical log interpretation should consist of all processes of determining information from geophysical logs. All geophysical log interpretation must be done by a qualified log analyst. The log analyst must be able to demonstrate competence through background, training, and experience when so called upon. It must be the CONTRACTOR'S responsibility to assure that all log analyses and/or interpretations are made by a person so qualified.

Spontaneous Potential Log. (self-potential) Records the natural potential developed between the borehole fluid and the surrounding rock materials. All spontaneous potential measurements are made in an uncased borehole. Measurements are made in millivolts and millivolts per horizontal chart width are shown on the log heading, along with the polarity. The spontaneous potential log may be run in conjunction with resistivity logs which, collectively, are commonly called an "Electric log".

Resistance Logging. A resistance log measures the resistance, in ohms, of the earth materials lying between an inhole electrode and a surface electrode, or between two inhole electrodes. All measurements are made in an uncased borehole. A resistance log may consist of a single-point, point-resistance, or single-electrode systems. The number of ohms per horizontal chart width are indicated on the log heading.

Resistivity Logging. Resistivity logging includes all devices which measure the electrical resistivity of a known or assumed volume of earth material under direct application of an electric current or an induced electric current. Measurements are made in ohm-meters and/or ohm-feet. Multiple-electrode resistivity measurements include such logs as the short and long normal, lateral, focused, wall resistivity, microfocused, and induction. Trade names applied to these logs can be substituted for the generic log types provided the generic type is referenced.

Natural-Gamma Logging. Records of the amount of natural-gamma radiation emitted by earth materials are called natural-gamma logs. Natural-gamma radiation measuring devices include thallium-activated sodium iodide crystals (scintillator) and Geiger-Mueller (G-M) tubes. Measurements are made in counts per second or seconds per count and should be related to API gamma-ray units and to a field standard in which the response of the logging equipment is checked periodically.

Accoustical Logging. An accoustic log (sonic log) is a record of the transit time of an acoustic pulse between transmitters and receivers in a probe. Measurements are recorded in microseconds per foot. Calibration points appear on the log preferably before and after the run, as an indication of the uphole system drift.

Caliper-Logging. A record of the average borehole diameter is called a caliper log. Measurements are made with a probe employing three or more arms or feelers hinged at the upper end and maintained against the hole wall by springs. Calibration to a known diameter is made before and after a run. Measurements are recorded in the inch-foot and/or metric system, and are so designated on the log heading.

Temperature Logging. The continuous record of the temperature of the environment immediately surrounding a sensor in a borehole is called temperature log. Where possible, a temperature log should be run simultaneously with a differential-temperature log. Sensors are calibrated with an accurate thermometer in a stabilized fluid bath. Measurements are recorded in degrees Centigrade or Fahrenheit. The run number and the direction of the probe during logging, up or down, appear on all logs.

Fluid-Movement Logging. Fluid-movement logging include all technique for measuring natural and/or artificially induced flow within a single borehole. Devices used to measure the vertical and horizontal components of flow in a single borehole may include impeller flowmeters, thermal flowmeters, and various systems for injecting and detecting radioactive and chemical tracers. Measurements shall be made in the inch-foot and/or metric systems per unit of time, or in graphic form showing percentage of flow past any given point. A caliper log should be made in conjunction with any fluid-movement log.

Photographic Logging. A photographic log records on photographic film, videotape, and/or prints made therefrom, the environment in a cased, uncased, or screened borehole or any combination thereof. The photographic record is made in two and/or three dimensions and may be in color or black and white. Photographs should be spaced covering a minimum five foot interval of well or borehole unless otherwise stipulated in the contract or by the OWNER or his authorized agent. All photographs shall be marked as to depth below ground surface.

HOLE LOCATION AND PURPOSE

†45.100-000-000. ***Hole Location and Purpose.*** The CONTRACTOR is to construct a test hole at ____________ to obtain information regarding the depth, thickness and water-yielding potential of the formations encountered. Geographic location shall be stated in terms of coordinates such as quarter section, township, and range, or by other suitable description relative to fixed reference points.

DRILLING METHODS

45.010-000-000. ***Contractor's Choice.*** The CONTRACTOR shall provide all equipment that will assure proper execution of the test drilling and sampling program specified herein. (Selected from Article 46.100-000-000.)

45.020-000-000. ***Driven Well Point Method.*** A driven well point shall be used.

45.030-000-000. ***Jetting or Hydraulicing Method.*** The test hole shall be drilled by the Jetting or Hydraulicing Method. The CONTRACTOR shall provide sufficient water supply from a source approved by the OWNER and a pump or pumps to properly operate the equipment.

45.040-000-000. ***Reverse Hydraulic Rotary Method.*** The test hole shall be drilled using the Mudless Reverse Rotary Method. The CONTRACTOR shall provide sufficient water supply from a source approved by the OWNER and a pump or pumps to properly operate the equipment. The CONTRACTOR shall be responsible for designing and controlling a drilling program that conforms to sampling method requirements in accordance with Article 45.080-000-010 (Formation Sample Size Handling and Identification).

45.050-000-000. ***Air Rotary Method.*** The test hole shall be drilled using the Hydraulic Air Rotary method. The CONTRACTOR shall be responsible for designing and controlling a drilling program that conforms to sampling method requirements in accordance with Articles 45.080-000-010 (Formation Sample Size, Handling and Identification).

45.060-000-000. ***Rotary Method.*** The test hole shall be drilled using the Hydraulic Mud Rotary method. The CONTRACTOR shall be responsible for designing and controlling a drilling program that conforms to sampling method requirements in accordance with Article 45.080-000-010 (Formation Sample Size, Handling and Identification).

45.070-000-000. ***Combined Driving and Drilling Method.*** The test hole shall be constructed by driving and drilling. In unconsolidated formations alternate driving of casing and bailing is anticipated followed by drilling in consolidated formations, when encountered.

Note: † Indicates fill-in is required.

†45.000-000-000. *Cable Tool Method.* The test hole shall be drilled by the Cable Tool method. In unstable unconsolidated formations the hole shall be advanced by driving the casing and bailing, and no sample shall be taken except when the casing has been driven ahead of the bottom of the hole; or in stable unconsolidated formations, samples shall be taken by drilling ____________ feet and bailing before or after driving the casing to the bottom of the drilled interval. In consolidated formations, the hole is advanced by drilling and samples by bailing. Casing may be run later to insure that the hole does not cave. The CONTRACTOR shall be responsible for designing, controlling, and carrying out a drilling program that conforms to sampling method requirements in accordance with Articles 45.000-000-010.

DRILLER'S LOGS AND REPORTS

45.001-000-000. *Driller's Log.* During the drilling of the test hole the Contractor shall prepare and keep a complete log setting forth the following:

1. The reference point for all depth measurements.
2. The depth at which each change of formation occurs.
3. The depth at which the first water was encountered.
4. The depth at which each stratum was encountered.
5. The thickness of each stratum.
6. The identification of the material of which each stratum is composed, such as:
    a. Clay
    b. Sand or Silt
    c. Sand and Gravel—Indicate whether gravel is loose, tight, angular or smooth; color.
    d. Cemented formation—Indicate whether grains (if present) have natural cementing material between them; e.g. silica, calcite, etc.
    e. Hard rock—Indicate whether sedimentary bedrock, or igneous (granite-like, basalt-like, etc.)
7. The depth interval from which each water and formation sample was taken.
8. The depth at which hole diameters (bit sizes) change.
9. The depth to the static water level (SWL) and changes in SWL with well depth.

If a test well is constructed the CONTRACTOR shall also report:

10. Total depth of completed well.
11. Any and all other pertinent information for a complete and accurate log, e.g., temperature, pH and appearance (color) of any water samples taken.
12. Depth or location of any lost drilling fluids, drilling materials or tools.

13. The depth of the surface seal, if applicable.
14. The nominal hole diameter of the well bore above and below casing seal.
15. The amount of cement (number of sacks) installed for the seal, if applicable.
16. The depth and description of the well casing.
17. The description (to include length, diameter, slot sizes, material, and manufacturer) and location of well screens, or number, size and location of perforations.
18. The sealing off of water-bearing strata, if any, and the exact location thereof.

15.002-000-000. ***Daily Driller's Report.*** During the drilling of the test hole or its conversion into a test well, a daily, detailed driller's report shall be maintained and delivered upon request to the **OWNER** or his representative at the well site. The report shall give a complete description of all formations encountered, number of feet (meters) drilled, number of hours on the job, shutdown due to breakdown, the water level in the well at the beginning and end of each shift, water level at each change of formation if readily measurable with the drilling method used, feet of casing set, and such other pertinent data as may be requested by the **OWNER** or his representative. In rotary drilling, the fluid level in the hole should be measured daily prior to starting pumps.

Driller's Log. During the drilling of the test hole the **CONTRACTOR** shall prepare and keep a complete log setting forth the following:

1. The reference point for all depth measurements.
2. The depth at which each change of formation occurs.
3. The depth at which the first water was encountered.
4. The depth at which each stratum was encountered.
5. The thickness of each stratum.
6. The identification of the material of which each stratum is composed, such as:
   a. Clay
   b. Sand or Silt
   c. Sand and Gravel—Indicate whether gravel is loose, tight, angular or smooth; color.
   d. Cemented formation—Indicate whether grains (if present) have natural cementing material between them, e.g. silica, calcite, etc.
   e. Hard rock—Indicate whether sedimentary bedrock, or igneous (granite-like, basalt-like, etc.)
7. The depth interval from which each water and formation sample was taken.
8. The depth at which hole diameters (bit sizes) change.
9. The depth to the static water level (SWL) and changes in SWL with well depth.

If a test well is constructed the CONTRACTOR shall also report:

10. Total depth of completed well.
11. Any and all other pertinent information for a complete and accurate log; e.g., temperature, pH, and appearance (color) of any water samples taken.
12. Depth or location of any lost drilling fluid, drilling materials or tools.
13. The depth of the surface seal, if applicable.
14. The nominal hole diameter of the well bore above and below casing seal.
15. The amount of cement (number of sacks) installed for the seal, if applicable.
16. The depth and description of the well casing.
17. The description (to include length, diameter, slot sizes, material, and manufacturer) and location of well screens, or number, size and location of perforations.
18. The sealing off of water-bearing strata, if any, and the exact location thereof.

13.063-000-000. ***Penetration Rate Log.*** During the drilling of the hole, a time log shall be kept showing the actual penetration time required to drill each foot of hole. The types of bits used in each portion of the hole shall be noted in this log—drag, roller, button or percussion type and whether designed for soft, medium, or hard formations, together with approximate weight on the bits during the drilling of the various types of formations in the various sections of the hole.

Driller's Log. During the drilling of the test hole the CONTRACTOR shall prepare a complete log setting forth the following:

1. The reference point for all depth measurements.
2. The depth at which each change of formation occurs.
3. The depth at which the first water was encountered.
4. The depth at which each stratum was encountered.
5. The thickness of each stratum.
6. The identification of the material of which each stratum is composed, such as:
   a. Clay
   b. Sand or Silt
   c. Sand and Gravel—Indicate whether gravel is loose, tight, angular or smooth; color.
   d. Cemented formation—Indicate whether grains have natural cementing material between them; e.g., silica, calcite, etc.
   e. Hard rock—Indicate whether sedimentary bedrock or igneous (granite-like, basalt-like, etc.)
7. The depth interval from which each water and formation sample was taken.
8. The depth at which hole diameters (bit sizes) change.

9. The depth to the static water level (SWL) and changes in SWL with well depth.

If a test well is constructed the CONTRACTOR shall also report:

10. Total depth of completed well.
11. Any and all other pertinent information for a complete and accurate log; e.g., temperature, pH, and appearance (color) of any water samples taken.
12. Depth or location of any lost drilling fluid, drilling materials or tools.
13. The depth of the surface seal, if applicable.
14. The nominal hole diameter of the well bore above and below casing seal.
15. The amount of cement (number of sacks) installed for the seal, if applicable.
16. The depth and description of the well casing.
17. The description (to include length, diameter, slot sizes, material, and manufacturer) and location of well screens or number, size and location of perforations.
18. The sealing off of water-bearing strata, if any, and the exact location thereof.

Daily Driller's Report. During the drilling of the test hole or its conversion into a test well, a daily, detailed driller's report shall be maintained and delivered upon request to the OWNER or his representative at the well site. The report shall give a complete description of all formations encountered, number of feet (meters) drilled, number of hours on the job, shutdown due to breakdown, the water level in the well at the beginning and end of each shift, water level at each change of formation if readily measurable with the drilling method used, feet of casing set, and such other pertinent data as requested by the OWNER or his representative. In rotary drilling, the fluid level in the hole should be measured daily prior to starting pumps.

45.004-000-000. ***Stratigraphic Log.*** The stratigraphic log shall be prepared by a qualified geologist to accompany the set of drilling samples, noting depth, strata thickness, lithology, including size, range and shape of constituent particles, smoothness, rock type, rate of penetration, and such special notes as might be helpful. The material will be described according to one of the standard size grade scale shown in Table 1.

Driller's Log. During the drilling of the test hole the CONTRACTOR shall prepare a complete log setting forth the following:

1. The reference point for all depth measurements.
2. The depth at which each change of formation occurs.
3. The depth at which the first water was encountered.
4. The depth at which each stratum was encountered.
5. The thickness of each stratum.

Table 1

VARIOUS SIZE GRADE SCALES IN COMMON USE

Udden-Wentworth	ϕ values	German Scale[1] (after Atterberg)	USDA and Soil Sci. Soc. Amer.	U.S. Corps of Engrs., Dept. Army and Bur. Reclamation[2]
Cobbles		(Blockwerk) 200 mm	Cobbles	Boulders
			80 mm	10 in.
64 mm	-6			Cobbles
Pebbles		Gravel (Kies)		3 in.
4 mm	-2		Gravel	Gravel
				4 mesh
Granules				Coarse sand
2 mm	-1	2 mm	2 mm	10 mesh
Very coarse sand			Very coarse sand	
1 mm	0		1 mm	
Coarse sand			Coarse sand	Medium sand
		Sand		
0.5 mm	1		0.5 mm	
				40 mesh
Medium sand			Medium sand	
0.25 mm	2		0.25 mm	
Fine sand			Fine sand	Fine sand
0.125 mm	3		0.10 mm	
Very fine sand			Very fine sand	200 mesh
0.0625 mm	4	0.0625 mm		
			0.05 mm	
Silt		Silt		
			Silt	Fines
0.0039 mm	8			
		0.002 mm	0.002 mm	
Clay		Clay (Ton)	Clay	

[1] Subdivisions of sand sizes omitted.

[2] Mesh numbers are for U.S. Standard Sieves: 4 mesh = 4.76 mm, 10 mesh = 2.00 mm, 40 mesh = 0.42 mm, 200 mesh = 0.074 mm.

6. The identification of the material of which each stratum is composed, such as:
   a. Clay
   b. Sand or Silt
   c. Sand and Gravel—Indicate whether gravel is loose, tight, angular or smooth; color.
   d. Cemented formation—Indicate whether grains have natural cementing material between them; e.g., silica, calcite, etc.
   e. Hard rock—Indicate whether sedimentary bedrock or igneous (granite-like, basalt-like, etc.)
7. The depth at which each sample was taken.
8. The depth at which hole diameters (bit sizes) change.
9. The depth to the static water level (SWL) and changes in SWL with well depth.

If a test well is constructed the CONTRACTOR shall also report:

10. Total depth of completed well.
11. Any and all other pertinent information for a complete and accurate log; e.g., temperature, pH, and appearance (color) of any water samples taken.
12. Depth or location of any lost drilling fluid, drilling materials or tools.
13. The depth of the surface seal, if applicable.
14. The nominal hole diameter of the well bore above and below casing seal.
15. The amount of cement (number of sacks) installed for the seal, if applicable.
16. The depth and description of the well casing.
17. The description (to include length, diameter, slot size, material, and manufacturer) and location of well screens, or number, and size and location of perforations.
18. The sealing off of water-bearing strata, if any, and the exact location thereof.

Daily Driller's Report. During the drilling of the test hole or its conversion into a test well, a daily, detailed driller's report shall be maintained and delivered upon request to the OWNER or his representative at the well site. The report shall give a complete description of all formations encountered, number of feet (meters) drilled, number of hours on the job, shutdown due to breakdown, the water level in the well at the beginning and end of each shift, the water level at each change of formation if readily measurable with the drilling method used, feet of casing set, and such other pertinent data as requested by the OWNER or his representative. In rotary drilling, the fluid level in the hole should be measured daily prior to starting pumps.

Penetration Rate Log. During the drilling of the hole, a time log shall be kept showing the actual penetration time required to drill each foot of hole. The types of bits used in each portion of the hole shall be noted in this log—drag, roller, button or percussion type and whether designed for soft, medium or hard formations, together with approximate weight on the bits during the drilling of the various types of formations in the various sections of the hole.

GEOPHYSICAL/MECHANICAL LOGS

†45.000-100-000. ***Geophysical/Mechanical Logs.*** When called for under the provisions of the contract the CONTRACTOR shall perform or have performed the following logs: ______, ______, ______, ______, ______, ______, which shall meet all appropriate specifications defined in Article 44 under "Geophysical/Mechanical Logs".

- A. Spontaneous-Potential Logging
- B. Resistance Logging
- C. Resistivity Logging
- D. Natural-Gamma Logging
- E. Acoustic Logging
- F. Caliper Logging
- G. Temperature Logging
- H. Fluid-Movement Logging
- I. Photographic Logging

FORMATION SAMPLING METHODS

45.000-010-000. ***Contractor's Choice.*** The method of sampling will be left to the discretion of the CONTRACTOR; however, he must collect, identify and store representative samples in accordance with Article 45.00-000-010, collected with sufficient frequency and at sufficient increments of depth to permit a thorough evaluation of the water-bearing properties of the formations encountered in drilling the test hole.

45.000-020-000. ***Return Flow Method (Continuous).*** A return flow sample shall be taken by removing from the circulating drilling fluid a representative sample of the formation by either collecting same in a cutting sample box, a "shale shaker", a baffle in a ditch, or catching it in a bucket and allowing the sample to settle out. Provision shall also be made to obtain a record of circulation time and probable depth of the formation from which the cuttings are derived. Drill cutting samples collected at specified depth intervals shall be placed in approved containers and identified as specified in Article 45.000-000-010. The samples shall be stored in a safe place by the CONTRACTOR.

†45.000-030-000. ***Return Flow Method (Circulated).*** A return flow sample shall be taken by removing from the discharge fluid a representative sample of the formation by either collecting same in a cutting sample box, a "shale shaker", a baffle in a ditch, or catching it in a bucket and allowing the sample to settle out. The penetration of the bit shall stop when the bottom of the sampling interval is reached for such time as is required for all the cuttings to move from the last drilled section of the hole and settle at the sampling point. The return [illegible] and sample catching device shall be cleaned of all cuttings after each sample is taken. A cutting sample shall be carefully collected from the sampling point. Drill cutting samples collected at specified depth intervals shall be taken by the CONTRACTOR. The total sample obtained from each interval shall be mixed and quartered until sufficient sample remains to furnish ________ (number) ________ (volume), representative samples. Drill cuttings shall be placed in approved containers and identified as specified in Article 45.000-000-010. The samples shall be stored in a safe place by the CONTRACTOR.

45.000-040-000. ***Auger Method.*** Formation samples obtained using the auger method are to be representative of the formation being penetrated. The samples will be collected, placed in approved containers, and stored in a safe place by the CONTRACTOR.

†45.000-050-000. ***Bailer Method.*** In clay and consolidated formations the sample shall be taken by bailing the hole clean then advancing the drill bit and collecting cuttings. In sand and gravel the sample shall be taken by driving casing ahead of the drill bit then bailing with a flat bottom or suction bailer. In stable unconsolidated formations, samples shall be taken by drilling ________ feet and bailing before and after driving the casing to the bottom of the drilled interval.

†45.000-060-000. ***Core Barrel Method.*** A core barrel shall be advanced, by being rotated or driven, its full length into the undisturbed formation. Once the core barrel has penetrated the desired interval, it shall be withdrawn and the core recovered and stored in a suitable core container. A core recovery of less than ________ percent will not be acceptable.

†45.000-070-000. ***Piston Tube Method.*** A piston tube sampler shall be driven into the undisturbed material at the bottom of the drilled hole to take formation core samples. This method is used to prevent the material in the core from expanding and to assure that the full core be held securely as the sampler is removed from the test hole. The cores are to be a minimum of ________ inches in diameter and ________ inches in length. Upon removal to the surface the sample is to be capped and sealed in its tube, placed in a sample box and stored in a safe place by the CONTRACTOR.

45.000-080-000. ***Split Spoon Method.*** A steel cylinder shall be driven vertically into the undisturbed formation at the bottom of the drilled hole. The cylinder will be returned to the surface and transferred to a suitable core container. No sample recovery of less than 50 percent will be accepted.

†45.000-090-000. ***Side-Hole Core Method.*** Formation samples will be taken using a ________ inch diameter side-hole core sampler. This unit must be set at depths as directed in such a way as to assure penetration of the hole wall to a sufficient depth to provide a recovery of a ____________ inch-long core. Side-hole cores will be taken after geophysical logs have been made, at depths specified by the **OWNER** or his representative. The samples shall be placed in a suitable container and identified as specified in Article 45.000–000–010, and stored by the **CONTRACTOR**.

Formation Sampling Interval

†45.000–001–000. ***Sampling by Formation Interval.*** Formation samples are to be taken starting at ____________ (specify depth, static water level, bottom of clay, etc.) for each formation change and continuing to ____________ (a specified depth or total depth of the test hole). Special care shall be taken in collecting samples from expected producing zones.

†45.000–002–000. ***Sampling by Measured Intervals.*** Formation samples are to be taken at ____________ foot (____________ meter) intervals. Special care shall be taken in collecting samples from expected producing zones, wherein samples shall be taken at ____________ foot (____________ meter) intervals.

†45.000–003–000. ***Sampling by Measured and Formation Interval.*** Formation samples shall be collected each ________ foot (________ meter), starting at ____________, and at any pronounced change of formation. Special care shall be used for collecting samples from zones that are expected to be producing zones, wherein samples shall be collected at ________ foot (________ meter) intervals.

Water (Aquifer) Sampling

45.000–000–100. ***Water Sampling.*** Water samples shall be taken for analysis from each aquifer. Samples shall be obtained in the following manner:

1. A well, in a consolidated formation shall be equipped with an assembly which includes an inner perforated pipe with the bottom plugged and packers located above and below the target aquifer. The inner pipe shall then be pumped at a rate of at least 10 GPM until a clear sample is obtained for analysis. This step shall be repeated for each aquifer.
2. A well, in unconsolidated formations, shall be equipped with an assembly which consists of a wound screen 5 feet in length set opposite each potential aquifer. Gravel is to be placed around the screen or clear water is to be pumped via reverse normal flow through the screen to cause the formation to collapse on the screen; or, a well point shall be driven into the undisturbed aquifer. Water shall then be pumped at 10 or more GPM until clear, at which time a sample shall be taken. This shall be repeated for each aquifer intended for use.

The OWNER or his agent may require, for reasons of inferior water quality, etc., the sealing or walling off of an aquifer in screened wells or he may, by special price agreement, require specified aquifers cemented off in non-screened wells. Samples obtained by air pumping of any type will not be acceptable.

FORMATION SAMPLE SIZE, HANDLING AND IDENTIFICATION

45.000-000-010. ***Size of Sample, Containers, Identification, Storage and Transfer.***

Size of Sample

__________ (number) __________ (volume) representative samples shall be obtained from each sampling interval. In most instances more cuttings will be recovered than required. The total volume of cuttings shall be thoroughly mixed and quartered until the number of volume of samples required are obtained as a residual.

Containers

Immediately after retrieval, formation samples shall be placed in approved containers, securely closed to avoid spillage and contamination, and clearly labeled with the following information:

1. Location of the well
2. Name or number of the well
3. Depth interval represented by the sample
4. Date taken
5. Time taken

Identification, Storage and Transfer

Formation samples, immediately after being placed in container, shall be labeled clearly, either directly on the container or on a tag attached thereto, using ink, indelible pencil, or other medium that is resistant to moisture and sunlight. The label shall not be readily removable from the container. The CONTRACTOR shall be responsible for the safe storage of formation samples until such times as they are accepted by the OWNER. Time, place, and mode of delivery shall be as directed by the OWNER.

For wells which may or will utilize screens, the CONTRACTOR shall obtain additional samples as required in water-bearing formations for analysis by a laboratory or screen manufacturer. Duplicate samples shall be retained in a safe place until the results of the analysis are received.

METHOD OF PAYMENT FOR TEST HOLES AND SAMPLES

45.000-000-001. ***Method of Payment.***

Option A (Lump Sum). All of the work performed under this Article (45) shall be paid for as a lump sum.

Option B (Time and Material): All of the work performed under this Article (45) shall be paid for on the basis of the price bid for well construction equipment per hour plus material at its cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (45) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid.

a. Test Hole Construction	Per Foot
b. Geophysical/Mechanical Logs	Unit Price/Foot
c. Stratigraphic Logs	Lump Sum
d. Formation Sampling (Per Sample)	Unit Price
e. Water Sampling (Per Sample)	Unit Price
f. Services of Log Analyst	Lump Sum

Article 46
Well Construction

PREAMBLE

The **CONTRACTOR/OWNER** or his Representative, through the use of information gathered by geophysical methods and/or existing local well records and/or the previous drilling of a test hole on the site of the production well, can determine the type of well needed to obtain the amount of water required. This knowledge of the character and depth of the producing zone and of the overlying formations will allow the choice of the construction method best suited to the type well required.

In determining the procedure to be followed in constructing a well there are two factors that predominate and must be considered before detailed planning can continue. These factors are the type well desired, and the method of its construction. Following are the types of wells and the methods to be used for their construction.

For the purpose of these standards the types of wells are defined as follows:

Unconsolidated Formation Pit Well (Bored or Dug Well). This large-diameter well is built to obtain water from the unconsolidated materials that normally occur in the first 50 to 100 feet (15 to 30 m) beneath the surface. In this type well, which may range from 3 to 20 feet (1 to 6 m) in diameter and 10 to 100 feet (3 to 30 m) in depth, the walls of the hole are curbed (lined) in such a way as to prevent cave-in of the walls yet still allow seepage of ground water into the well bore to produce a reservoir of water. It is ordinarily constructed by digging or boring.

The Radial Collector Type Well. This type is a variant of the dug well, and usually consists of a concrete shaft or caisson from which horizontal intake pipes project radially. Because of their size (diameter three feet and larger, and intake pipes 100-500 feet long) and the fact that they can require specialized structural design, construction of radial collector wells will not be covered by these standards; however, use of these wells when applicable, is acceptable.

Unconsolidated Formation Natural Filter Well. This type of well is built to obtain water at various depths from unconsolidated formations which can be stabilized naturally by development following the installation of the casing and screen. A well of this type may be constructed by jetting, boring, driving, drilling or a combination of methods.

Unconsolidated Formation Artificial Filter Well. This type of well is built to obtain water at various depths from unconsolidated formations that cannot be stabilized by the use of a casing/screen combination and development only, but in addition requires the use of a material that is coarser than the formation material in the screened interval. This added material acts as an additional screen to prevent the fine aquifer materials from entering the well. This type of well may be constructed by boring, driving, or drilling, or a combination of two or more of these methods. This type of construction is also essential in some large-diameter wells drilled with bucket augers or reverse-circulation rotary drilling methods.

Consolidated Formation Open Borehole Partially Cased Well. This type of well is built to obtain water at various depths from consolidated formations, either fractured or unfractured. It is not cased or screened in the producing zone for no formation stabilization or filtering is needed, but may be cased through the formations above the producing zone, if they are unconsolidated or unstable, to prevent borehole collapse or to exclude water of undesirable quality. This type of well is constructed by drilling.

Unstable-Consolidated Formation Partially Cased Well. This type of well is built to obtain water from unstable, potentially caving formations. It is usually screened through the producing zone and may, under some conditions, require the addition of coarse filter material. The well may not be cased through all the formations above the producing zone, except to exclude water of undesirable quality, but will have a surface seal casing. This type of well is constructed by drilling.

Methods of Construction

Construction methods are many and varied, ranging from simple digging with hand tools to high speed drilling with sophisticated equipment. The most commonly used methods are described below:

Digging Method. In this method the hole is constructed by digging to the desired diameter and depth with hand or power tool. The dug out materials are removed by lifting them from the hole in some type of container. The hole is shored, staved, or cased as the depth is increased. When casing is used, a common practice is to add casing at the surface, allowing it to sink of its own weight as the hole is excavated below the bottom of the casing.

Boring Method. In this method the hole is constructed by the use of a selected diameter hand or power auger which is turned to bore the hole to the desired depth. Cuttings are removed by pulling and emptying the auger or bucket or by the screw action of the auger flite itself.

Driving Method. In this method the hole is constructed by forcing a casing equipped with a drive point into the ground by a series of blows, either manually or machine-delivered, on the top of the casing. Driven wells (or "well points") should be installed only in soft formations that are relatively free of cobbles or boulders. They are feasible only where lifts are shallow and the quantity of water desired is small. Well points can be installed by hand or machine.

Jetting and Hydraulicing Method. The jet drill is basically a combination percussion unit and pressure pump. The pressure pump is mounted on the machine together with pipe and hose connections leading from the pump to the drill pipe, with a return hose from the well casing to a pit or other suitable container. A suction hose returns the water from the pit or container to the pump. The drill pipe consists of a small diameter standard pipe with a bit or chisel attached to the bottom section. Water is forced down through the drill pipe by means of the pressure pump and out through holes in the bit. This water, being under pressure, carries the cuttings to the surface through the space between the casing and the drill pipe. The lifting and dropping action of the drill pipe chops up the material in the hole and loosens it so that it may be washed to the surface. This method uses a short, fast stroke and is very effective in soft ground, sand and gravel, or other loose unconsolidated formations. This method is best suited for smaller holes of from 2 to 4 inch diameter (5 to 10 cm.)

A percussion machine is also used for drilling holes by the hydraulicing method. The difference between this and the jetting method is that with the hydraulicing method no pressure pump is needed. The hydraulicing unit utilizes a bit with an opening at the top and a valve seat and ball check valve above it. Water is directed into the hole by gravity to the space between the drill pipe and the casing. The up and down motion of the drill pipe acts as a displacement pump. The ball check valve opens on the down stroke and draws material and fluid into the drill pipe. The valve closes on the up stroke, holding the slurry within the pipe. Eventually the pipe fills up and the mixture of fluid and cuttings are discharged at the surface. Like jetting, the hydraulicing method is fast and efficient in relatively soft formations such as clay and sand.

Cable Tool Method. The cable tool method is used to construct wells by alternately lifting and dropping a set of drilling tools suspended on a wire cable so that with each stroke the drill bit strikes the bottom of the hole. The repeated action of the percussion drill permits bit penetration of the underground formations. The loosened material and drill cuttings are mixed with drilling water by action of the bit and the resulting slurry must be removed from the drill hole by a bailer or sand pump. In drilling a dry hole, water must be added periodically to replace that removed with the drill cuttings. Tools for drilling and bailing are carried on separate lines or cables. Each cable is spooled on a separate drum.

In cable tool or percussion drilling there are basically three major operations: first, the drilling of the hole by chiseling or crushing the rock, clay, or other material by the impact of the drill bit; second, removing the cuttings with a bailer as cuttings accumulate in the hole; and third, driving or forcing the well casing down into the hole as the drilling proceeds. Well casing used in most percussion-type drilling operations usually ranges from four to 24 inches (10 to 61 cm) in diameter. This casing is used to keep the well bore from collapsing and to prevent surface or subsurface leakage of water or contaminants into the well bore.

Conventional Fluid Rotary Drilling Method. In the conventional mud-rotary method of drilling, drilling is accomplished by rotating a drill pipe and bit by means of a power drive. The drill bit cuts and breaks up the rock material as it penetrates the formation. Drilling fluid is pumped through the rotating drill pipe and holes in the bit. This fluid swirls in the bottom of the hole, picking up material broken by the bit, then flows upward in the well bore, carrying the cuttings to the surface.

The drill pipe and bit move progressively downward, deepening the hole as the operation proceeds. At the land surface, the drilling fluid flows into a settling pit where the cuttings settle to the bottom. From the settling (mud) pit the fluid overflows into a second pit from which it is picked up through the suction hose of the mud pump and recirculated through the drill pipe. In the rotary drilling method the well casing is not introduced into the hole until drilling operations are completed, the walls of the hole being supported by the pressure (weight) of the drilling fluid.

Reverse Circulation Drilling Method. In reverse circulation drilling, instead of circulating the drilling fluid through the drill pipe and up the outside of the pipe, the process is reversed. Fluid is fed down through the space between the wall of the hole and the drill pipe and it is then pumped up, together with the cuttings, through the hollow part of the drill pipe and out a discharge pipe. With the addition of air (applied via a compressor through piping along the drill stem) drilling depths have been increased in one instance, from 450 to 1,000 feet. Of particular importance is the use of a light (nearly clear) drilling fluid which eliminates the need for a viscous and heavy drilling mud used in conventional rotary drilling. The mud sometimes tends to seal-off water-bearing formations. The use of a relatively clear drilling fluid is possible because drilling is rapid; however, a substantial quantity of fluid must be on hand to maintain an open hole.

This method is used for rapid drilling of large diameter holes in soft formations where small boulders are encountered. Boulders up to six inches (15 cm) in diameter can be brought up to the surface through the hollow drill pipe. Such performance is possible because of the extremely high velocity of the fluid as it is drawn up through the drill pipe by the suction pump. In the reverse circulation method, holes 16 inches to 72 inches (40.6 to 182.9 cm) in diameter have been drilled. The walls of the hole are held in place by the pressure of the fluid against the sides of the hole.

Air Rotary Drilling Method. In the air rotary method of drilling, air serves as the fluid and excavation is accomplished exactly as is done in the conventional rotary method. The bit cuts and breaks up the formation.

Air is forced down through the drilling pipe and out through holes at the bottom of the rotary bit. A stream of water is often introduced into the air system to help cool the drill bit and control dust. The air serves both to cool the drill bit and force cuttings up and out of the hole. The cuttings move up in the annular space between the drill pipe and the wall of the hole, and are collected at the top. Air is used principally in hard clay or rock formations, because once the air pressure is turned off, loose formations tend to cave-in against the drill pipe. This method is not generally recommended for drilling in unconsolidated materials because the quality of the samples are usually poor. Foaming additives are occasionally used to increase the up-hole carrying capacity of the return air.

Down-the-Hole (Down-Hole Hammer, Hammer Drilling) Method. The down-the-hole method involves a pneumatically operated bottom-hole drill that efficiently combines the percussion action of cable tool drilling with the turning action of rotary drilling. The pneumatic drill can be used on a standard rotary rig with an air compressor of sufficient capacity. It is used for fast and economical drilling of medium to extremely hard formations. Fast penetration results from the blows transmitted directly to the bit by the air piston. Continuous hole cleaning exposes new formation to the bit and practically no energy is wasted in redrilling old cuttings. Down-the-hole drilling is generally the fastest method of penetration in hard rock. The bit is turned slowly (5 to 15 rpm) by the same method by which the drill bit in the fluid or air drilling operation is rotated. Foaming additives are occasionally used to increase the up-hole carrying capacity of the return air.

METHODS OF CONSTRUCTION

46.100-000-000. The CONTRACTOR shall choose the construction method(s) to be used. These are:

Digging or Boring
Driving
Cable Tool (Percussion)
Jetting or Hydraulicing
Conventional Fluid Rotary Drilling
Reverse Circulation Rotary Drilling
Air Rotary Drilling
Down-the-hole Drilling

46.010-000-000. ***Production Zone Protection.*** Material used by **CONTRACTOR** to prepare the drilling fluid shall be composed of fresh, non-polluted water and sodium bentonite type drilling clay commercially processed to meet or surpass the viscosity specification in the American Petroleum Institute "Std. 13-A for Drilling Fluid Materials". All other drilling fluid additives used will comply with recognized industry standards and practices, and they will be applied and used as prescribed by the manufacturer. It is expressly understood that toxic and/or dangerous substances will not be added to the drilling fluid.

The drilling fluids program should be agreed to by the **CONTRACTOR** and the **OWNER** or **PROJECT REPRESENTATIVE**. Selection and use of the drilling fluid materials shall be a part of this agreement. The **CONTRACTOR** shall be responsible for maintaining the quality of the drilling fluid to assure 1) protection of water bearing and potential water bearing formations exposed in the bore hole, and 2) good representative samples of the formation materials.

The drilling fluid properties required will depend on: 1) the type and size of drilling equipment to be used, and 2) down hole conditions anticipated or encountered. Properties of the drilling fluid are to be measured in accordance with the procedures of the American Petroleum Institute R.P. 13-B—"Procedures for Testing Drilling Fluids". Samples tested are those caught at the rig pump suction with care taken to assure a true and representative sample. Tests should be conducted: 1) every 50 feet of depth or 2) every four circulating hours or 3) whenever conditions appear to have changed or problems arise.

1. Mud density: should be in the range of 9 pounds per gallon. (higher if necessary to control a formation over-pressure situation.)
2. Mud viscosity: should be kept as thin as practical and still retain formation stability and adequate hole cleaning. (Will depend on ascending velocity in annulus and is usually in the range of 30 to 40 seconds per quart for properly sized drilling equipment and in normal drilling situations).
3. Sand content: should not exceed 2 percent of volume.

The **CONTRACTOR** shall maintain current records on the site at all times to show: 1) time, depth and results of all mud tests, 2) all materials added to the system—kind, amount, time and depth, and 3) variances or modifications from agreed to mud program—time, depth, reason and authorization.

The **CONTRACTOR** is responsible for the removal of the drilling mud from the hole and the development of the well, as per Article 52 and related specifications on well development.

DRILLER'S LOGS AND REPORTS

46.001-000-000. *Logs.* The driller's log of the well, daily driller's reports, and stratigraphic log and penetration log (if required), etc., shall be prepared in accordance with Article 45.

TEMPORARY CAPPING

46.000-100-000. *Temporary Capping.* Any well that is to be temporarily removed from service, or which is completed for a period prior to being placed in service, or is left uncompleted due to a recess or delay in construction shall be capped with a water-tight welded or threaded cap or equipped with some other type of "vandal-proof" cover satisfying applicable state or local regulations or recommendations.

METHOD OF PAYMENT OF WELL CONSTRUCTION

46.000-010-000. *Method of Payment.*

Option A (Lump Sum): All of the work performed under this Article (46) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (46) shall be paid for on the basis of the per hour price bid for well construction equipment plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (46) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and or subcontracted services at the invoice price plus percent of add-on bid:

a. Well Construction	Unit Price
b. Geophysical/Mechanical Logs	Lump Sum
c. Formation Sampling (Per Sample)	Unit Price
d. Services of Log Analyst	Lump Sum
e. Temporary Capping	Lump Sum

Article 47
Well Casing Selection and Installation

PREAMBLE

Casing is installed to prevent the collapse of the walls of the borehole, to exclude, along with grouting, pollutants, either surface or subsurface, from entering the water source, and to provide a channel for conveying the water to the surface (or in the reverse direction for injection). Casing also provides a housing for the pump mechanism.

Casing must be strong enough to resist the pressures exerted by the surrounding materials, forces imposed on it during installation, and corrosion by soil and water environments. It must be of the proper length to accomplish its purpose of providing a channel from the source to the surface through unstable formations, and through zones of actual or potential contamination. Casing should extend from above known levels of flooding to at least five feet below the lowest estimated pumping level of a well, screened in sand and gravel. In consolidated formations casing should be driven five feet into firm bed rock and cemented in place. Care must be exercised when placing casing. In areas where subsidence or shifting forces are known or expected to occur a self-sealing slip joint may be installed in the casing to allow for vertical movement and prevent collapse.

Steel is the material most frequently used for well casing. Plastic well casing is now being used successfully in many parts of the country. Concrete, fiberglass and asbestos cement casing have also been used.

Less common materials such as stainless steel, cupro-nickel alloys, silicon bronze, aluminum, and other nonferrous metals, can be used for casing in special situations where the natural soil and water-quality conditions dictate their employment. Because of their higher cost and usually lower strength, additional care should be exercised in their installation.

A number of technical and scientific organizations are active in promulgating pipe and casing specifications. Representative members of producers, consumers, and general interest groups develop specification details and tests which are then published by the associations involved. Prominent and most active in connection with pipe and casing specifications are the American Society for Testing and Materials (ASTM), the American Petroleum Institute (API) and American Water Works Association (AWWA).

Such specifications serve three general functions. First, they stipulate mill testing standards and prescribe methods of measuring required mechanical and physical properties. Secondly, they establish a common ground of understanding between the casing buyer and the producer. They provide a shortcut for easy, accurate ordering, eliminating most of the requirements for detailed information which would otherwise be necessary without a specification number symbol. Finally, they serve as a quality warranty. When the mills affix the specifications number symbol to a length of materials, they certify that it is made to meet all of the requirements of the specifications.

Not all materials are covered by standard specifications and there are few actual casing specifications. Most of those employed in the water well industry are written for pipe wherein installation in a direction normal to the earth's surface has not been considered in their preparation.

The most commonly used lining materials are tubular-steel products. Steel is particularly suited to cable-tool drilling, because it is the only practical material that can withstand driving or the pressure imposed by jacking. Unfortunately, the terms "casing and pipe" are used interchangeably and designate a variety of tubular products; this is the source of much confusion in the field of water well construction. There is, however, a distinguishing difference between pipe and casing. Pipe is manufactured in cylindrical form at the producing mill, whereas casing is made cylindrical by a fabricator from steel sheets or plates produced at a mill. Thus, casing is essentially fabricated pipe. The reason for the difference in manufacture is because the demand for prefabricated pipe for use in the transmission of water, oil, and gas far exceeds the demand for casing.

There are three principal types of tubular-steel products in satisfactory use for water well casing. The first is line pipe and standard pipe made to conform to standards of the American Petroleum Institute (API) or American Society for Testing Materials (ASTM). Casing fabricated from structural steel plate to conform to ASTM specifications is the second type. A third type, referred to by manufacturers and fabricators as "well casing steel", is made from high strength carbon steel sheets. At present there are no standard specifications dealing with this material other than those of the individual manufacturer.

Although it is possible to have steel pipe or casing made to any desired diameter or thickness, manufacturers and fabricators produce the products in common demand. Pipe diameters range from 4 to 36 inches with thicknesses up to one-half inch. Casing is made from steel plate three-sixteenths to five-sixteenths of an inch thick with diameters between 6 and 30 inches. Sheet steel thicknesses run from 12 gage to 6 gage and is used in fabricating both single and double-wall casing in diameters of 6 to 24 inches.

Pipe made of concrete, both plain and reinforced, PVC, asbestos cement, stainless steel and other materials are covered by specifications of ASTM or AWWA. There are no casing specifications for these materials at present.

There are two principal methods for installing casing. They are driving (of which jacking is a variation) and lowering (of which "floating", a method employed where the casing load is great, such as in large-diameter deep wells, also is a variation).

All joints should be made in a manner suitable to the material to insure that they will be watertight where necessary. If joints are welded the standards of the American Welding Society should apply.

Regardless of size, weight or length of the well casing, it is important that it be properly seated to insure a satisfactory well. When casing is to be seated, (as contrasted to that which is suspended or "hung") it should be firmly positioned so that it will not move vertically (settle) or go out of alignment.

Selecting Casing Diameter

The diameter of well casing is best chosen as two nominal sizes larger than the bowl size of the pump that will be installed. Under no circumstances should it be less than one nominal size larger. Table 9 lists casing sizes recommended for wells of selected yield. These sizes were determined by taking the bowl sizes of the most efficient 1800 RPM vertical turbine pumps that could be used to pump a given quantity of water and specifying two nominal sizes larger for the casing. In making this determination of optimum casing sizes, velocity and head losses caused by the vertical movement of water from the entrance portion of the well through the casing to the pump intake were taken into account. The diameters specified are such that these head losses will be small. If the casing size is selected according to the listing, there should be adequate clearance for the vertical turbine pump. The pump shaft will be plumb and binding will not occur even if the casing is slightly out of line and not exactly plumb.

TABLE 2.—*For Line Shaft Turbines 1800 rpm*

Yield	Recommended casing size
Less than 100 gpm	6'' I.D.
75-175 gpm	8'' I.D.
150-400 gpm	10'' I.D.
350-600 gpm	12'' I.D.
600-1300 gpm	14'' O.D.
1300-1800 gpm	20'' O.D.
1800-3000 gpm	24'' O.D.
3000-4500 gpm	30'' O.D.
Over 4500 gpm	30'' O.D.

In large capacity wells, it is often advantageous from the standpoint of power efficiency and extended pump life to utilize larger diameter 1200 RPM bowls. The initial cost of a larger diameter well to accommodate this type of bowl is soon compensated for by the increased efficiency and longer life. Table 3 shows the casing sizes recommended for such yields.

TABLE 3.—*For Line Shaft Turbines 1200 rpm*

Yield	Minimum recommended casing size
1300-1800 gpm	20'' O.D.
1800-3000 gpm	24'' O.D.
3000-4500 gpm	26'' O.D.
Over 4500 gpm	30'' O.D.

For smaller capacity domestic wells similar problems of relating casing size to pump size occur. Table 4 gives recommended casing sizes.

Selecting Casing Thickness

The thickness of material used for well casing should be selected in accordance with good design practice and experience as applied to conditions found at the well site. The ability of a specified casing to resist external forces can be calculated theoretically. However, the effect of forces imposed on it during installation are not known with certainty and practical research into the ability of casing materials to withstand installation as well as subsurface stresses has not been done to any extent. Hydrostatic test pressures on pipe listed in manufacturers specification literature are internal pressures measured at the mill and do not necessarily relate directly to working pressures. Accordingly, designers must introduce safety factors to insure that the casing will resist the forces expected to occur.

TABLE 4.—*Casing Sizes—Domestic Wells*

Yield at 50' drawdown	Recommended casing diameter	Pump type		
		Jet	Turbine	Submersible
Less than 8 gpm	2"	X	X	
	3"	X	X	X
	4"	X	X	X
	5"		X	X
	6"			X
8 to 18.5 gpm	2"	X	X	
	3"	X	X	X
	4"	X	X	X
	5"		X	X
	6"			X
Greater than 18.5 gpm	3"	X		
	4"	X	X	X
	5"		X	X
	6"			X

The collapse strength of fabricated sheet steel pipe for various diameters and thickness has been calculated assuming the water level inside the casing is rapidly lowered and the water level outside remains static. Values are listed in Table 5.

Table 5 shows pressures at which it is estimated single casing will collapse if water is lowered on the inside of the casing, and the water on the outside remains static. When pumping cement behind a casing it must be kept in mind that cement weighs more than water, therefore the weight per cubic inch of cement must be calculated and the values in pounds used from the chart, rather than the "head in feet".

Standard steel line pipe thicknesses for various diameters are shown in Table 6, which is based on both the need for strength in various kinds of construction, and the desirability of long-life resistance to corrosion.

Suggested minimum thicknesses for standard steel plate and sheets are listed in Table 7. Similar recommendations for steel sheets (called "well casing steel") manufactured in accordance with specifications of steel producers are listed in Table 8. Suggested thicknesses for steel casing for various depth and diameters will be found in literature published by steel manufacturers and fabricators.

PVC Casing[*]

PVC (polyvinyl chloride) plastic pipe used for well casing shall conform to ASTM-2241-73 for well diameters up to 4 inches (See Table 9).

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[*] New ASTM standards are currently under review. When they become available they will replace those standards shown in Tables 9 and 10.

TABLE 5.—*Collapse Strength of Steel Pipe in Pounds Per Square Inch and Feet of Water Head*

Size of Pipe	No. 12 (Gauge)	No. 10 (Gauge)	3/16" (0.188")	1/4" (0.250")	5/16" (0.313")	3/8" (0.375")
8"						
lbs	127	275	646	1,532	2,992	5,170
ft	293	634	1,488	3,530	6,894	11,912
10"						
lbs	65	141	331	784	1,532	2,647
ft	150	325	763	1,806	3,530	6,099
12"						
lbs	38	81	191	454	887	1,532
ft	88	187	440	1,046	2,044	3,530
14"						
lbs	24	51	121	286	558	991
ft	55	118	279	659	1,286	2,283
16"						
lbs	16	34	81	191	374	646
ft	37	78	187	440	862	1,488
18"						
lbs		22	57	134	263	454
ft		51	131	309	606	1,046
20"						
lbs		17	41	98	192	331
ft		39	94	226	442	763
22"						
lbs			31	74	144	249
ft			71	170	332	574
24"						
lbs			24	57	111	191
ft			55	131	256	440
26"						
lbs			19	45	87	151
ft			44	104	200	348
28"						
lbs			15	36	70	121
ft			35	83	161	279
30"						
lbs				29	57	98
ft				67	131	226
32"						
lbs				24	47	81
ft				55	108	187
34"						
lbs				20	39	67
ft				46	90	155
36"						
lbs				17	33	57
ft				39	76	131

TABLE 6.—*Well Thicknesses for Steel* Water Well Pipe*

Nominal size in inches	Diameters in inches External	Internal	Wall thickness in inches	Weight in pounds per foot Plain ends	Threads and couplings
2	2.375	2.067	0.154	3.65	3.68
2½	2.875	2.469	0.203	5.79	5.82
3	3.500	3.068	0.216	7.58	7.62
3½	4.000	3.548	0.226	9.11	9.20
4	4.500	4.026	0.237	10.79	11.00
5	5.563	5.047	0.258	14.62	14.81
6	6.625	6.065	0.280	18.97	19.18
8	8.625	8.071	0.277	24.70	25.55
10	10.750	10.192	0.279	31.20	32.75
12	12.750	12.090	0.330	43.77	45.45
14	14.000	13.250	0.375	54.57	57.00
16	16.000	15.250	0.375	62.58	65.30
18	18.000	17.250	0.375	70.59	73.00
20	20.000	19.250	0.375	78.60	81.00

* Standard specifications of API, ASTM.

TABLE 7.1—*Steel Well Casing Fabricated From Standard* Plate or Sheets* (single casing)

Diameter (inches)	Thickness (inches)‡
6	0.1046 (12 gage)
8	0.1046 (12 gage)
10	0.1046 (12 gage)
12	0.1345 (10 gage)
14	0.1345 (10 gage)
16	0.1644 (8 gage)
18	0.1644 (8 gage)
20	0.1644 (8 gage)
22	0.2500
24	0.2500
30	0.2500

* Standard Specifications of ASTM.

† Use of this material is not recommended although it is used in some parts of the United States.

‡ EPA recommends that the minimum wall thickness for steel casing, to provide adequate life under moderately corrosive conditions, should be 1/4 inch (0.250 in.). For very corrosive conditions, the thickness should be correspondingly greater.

CASING SELECTION

47.100 000 000. ***Well Casing Selection.*** All well casing shall be new. They shall be made of ____________________ (material) which conforms to ____________________ (enter here the material specification including organization name or abbreviation, numerical designation and title or in some instances, trade name.) The casings shall be of the diameters and lengths specified in the following listing.

Diameter (inches) (cm) (I.D. or O.D.)	Weight (pounds/ft.) (kg/meter)	Length (feet) (meter)
__________	__________	__________
__________	__________	__________
__________	__________	__________

Table 8.1—*Steel Well Casing Fabricated From "Well Casing Steel" Sheets*†
(single casing except where noted)

Diameter (inches)	Thickness (inches)‡
6	0.1094 (12 gage)
8	0.1094 (12 gage)
10	0.1094 (12 gage)
12	0.1406 (10 gage)
14	0.1406 (10 gage)
16	0.1719 (8 gage)
18	0.1719 (8 gage)
20	0.1719 (8 gage)
22	Double thick (10 gage)
24	Double thick (10 gage)
30	Double thick (8 gage)

* Manufacturers specifications.
† Use of this material is not recommended although it is used in some parts of the United States.
‡ (Same note as in Table 7).

Table 9—*PVC Casing*
*ASTMD 2241–73**
SDR 21 (Type 1120–1220)

Nominal size	Outside diameter	Inside diameter	Minimum wall thickness
	Inches		
1.5	1.900	1.720	0.090
2	2.375	2.149	0.113
2.5	2.875	2.601	0.137
3	3.500	3.166	0.167
4	4.500	4.072	0.214

PVC casing for well diameters of 5 inches through 12 inches shall conform to ASTM–D1785–73 (See Table 10).

Table 10—*PVC Casing*
*ASTMD 1785–73**
Schedule 40 (Type 1120–1220)

Nominal size	Outside diameter	Inside diameter	Minimum wall thickness
	Inches		
5	5.563	5.047	0.258
6	6.625	6.065	0.280
8	8.625	7.981	0.322
10	10.750	10.020	0.365
12	12.750	11.938	0.406

* New ASTM Standards are currently under review. When they become available they will replace those standards shown.

All casing shall bear mill markings that will identify the material as that which is specified. If necessary, the CONTRACTOR shall furnish the engineer with a copy of the mill certificate for approval before delivery of the casing to the well site.

METHODS OF INSTALLATION

47.010-000-000. ***Driven (Well Point).*** A hole shall be bored with a hand or power-operated auger slightly larger in diameter than the well point. The hole shall be vertical and extend as far as possible into the water-bearing formation. The drive point and the appropriate number of sections of riser pipe (in lengths of 5 feet (1.5 m) or more) shall be assembled and inserted in the bored hole. If used, couplings shall have recessed ends and tapered threads so that when assembled no pipe threads are exposed. Pipe thread compound shall be applied to the threads to make the joints water tight. A malleable iron drive cap shall be fastened to the top of the assembly. Driving shall be done with a driving tool or maul suspended on a tripod or derrick. The riser pipe shall be guided to insure that the well will be vertical and if threaded turned with a wrench from time to time in a clockwise direction to insure that the threaded sections remain tight. It shall be the CONTRACTOR'S responsibility to utilize the equipment he deems suitable to insure a satisfactory well which will maintain alignment, plumbness and roundness during installation.

47.020-000-000. ***Jacking.*** Jacking is used to install casing when drilling wells with cable tools, especially when mud scows are used. A pulldown spread footing shall be installed around the well and the jacking force on the casing achieved by pulling down on the casing with the ram end of hydraulic jacks while the cylinder end is secured to the spread footing.

47.030-000-000. ***Driven (Drive Shoe).*** Casing may be driven either by percussion from the cable tool string, or by a pneumatic tool designed to drive casing through unconsolidated formations. When permanent well casing is driven, a standard drive shoe shall be welded or threaded on the lower end of the string of casing. The shoe shall have a beveled and tempered cutting edge of metal forged, cast or fabricated for this purpose. It shall be the CONTRACTOR'S responsibility to utilize the equipment he deems suitable to insure that the well will maintain alignment, plumbness, and roundness during installation.

47.040-000-000. ***Lowering.*** The lowering method is used to install a jointed casing string in a predrilled hole. The casing shall be lowered with the drilling machine, utilizing clamps, elevators or other mechanical devices.

47.050-000-000. ***Floating.*** Where the casing load is extremely large it may be desirable to "float" the casing into place. A float collar shall be installed on the casing at the appropriate place in the casing string or a float plug shall be installed in the casing string near the bottom. Where a float collar or float shoe is to be used a casing-size dummy (40 ft. (12.20

m) minimum length) shall be run into the hole first to insure that the hole is straight and free from obstruction which could result in a stuck casing.

Method of Joining

47.001–000–000. ***Contractor's Choice.*** Casing lengths shall be joined watertight by a method appropriate to the material used, as selected by the **CONTRACTOR** and approved by the **OWNER**, so that the resulting joint shall have the same structural integrity as the casing itself. If *metallic casing* is welded, the standards of the American Welding Society shall apply.

If *threaded and coupled joints* are used, couplings shall be API or equivalent, made up so that when tight all threads will be buried in the lip of the coupling.

Plastic casing sections shall be joined watertight by either solvent welding or fusion welding in accordance with the directions of the manufacturer of the materials used, or by the use of threaded and coupled joints.

When *concrete pipe* is used, the casing shall be joined in accordance with standards of the American Society for Testing and Materials or the American Water Works Association. Special care shall be taken to avoid chipping or cracking the casing.

When *asbestos cement pipe* is used, the casings shall be joined in accordance with standards of the American Water Works Association. Special care shall be taken to avoid chipping or cracking the casing.

Other Materials: Casing made of other materials (aluminum, copper, brass, fiberglass, etc.) shall be joined in accordance with the manufacturer's instructions.

Sanitary Protection of Well

47.000–100–000. ***Termination at Top of Well.*** At all times during the progress of the work the CONTRACTOR shall use reasonable precautions to prevent either tampering with the well or the entrance of foreign material into it.

Upon completion of the well, the CONTRACTOR shall install a suitable threaded, flanged, or welded cap or compression seal so as to prevent any pollutants from entering the well. The watertight casing, curbing, pitless adapter or pitless unit (if approved for use by federal, state or local regulations) of any well shall extend not less than 12 inches (30 cm) above the pumphouse floor or final ground level elevation, and not less than 12 inches (30 cm)[*] above the normally anticipated flood level of record. Any equipment which will permit direct open access to the well shall also meet the above height requirements and shall be sealed or screened so as to prevent entrance of foreign matter or contaminants. The ground immediately surrounding the top of the well casing or pitless unit shall be sloped away from the well. There shall be no openings in the casing wall below its top except for approved pitless well adapters or units, measurement access ports and grout nipples installed in conformance with these standards.

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[*] EPA recommends at least 24 inches (60 cm) above the highest known flood level.

The pitless adapter or unit, including the cap or cover, the pitless case and other attachments shall be designed and constructed to prevent the entrance of contaminants into the well from surface or near-surface sources. Pitless units shall be attached to the casing by threading or welding in a manner which will make the joint sound and watertight.

CASING SEATING

47.000-010-000. ***Unconsolidated Formations.*** In unconsolidated formations the casing is supported by the collapse and compaction during well development. The completion of the sanitary surface seal will assist in supporting the casing.

47.000-020-000. ***Consolidated Formations.*** In consolidated formations the casing should extend at least five feet into the formation to assure a proper seat and bottom seal. It shall be the responsibility of the **CONTRACTOR** to effect a proper seal. Where the casing is to be driven it shall be fitted with a drive shoe and shall be driven to refusal. Where the casing is to be placed (rather than driven), cement grout shall be placed in the bottom of the hole in accordance with Article 48.

PRESSURE TESTING OF SEATING

47.000-001-000. ***Pressure Testing of Seating.*** Where casing has been driven, pressure testing shall be employed immediately following installation to determine whether an air-tight seating has been accomplished. An appropriate temporary airtight cap is to be installed and a pressure of 7 to 10 pounds per square inch is to be maintained within the well, without the addition of more air, for a period of not less than one hour. Any loss of air shall be construed as indicating a defective seal. To correct such a defect, the **OWNER** shall require the **CONTRACTOR** to make the necessary repairs by either cementing the seating zone or by other means acceptable to both the **OWNER** and **CONTRACTOR**.

METHOD OF PAYMENT FOR CASING AND INSTALLATION

47.000-000-100. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (47) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (47) shall be paid for at the unit price bid per hour for well contion equipment per hour plus materials at cost plus per cent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (47) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

a. Casing Furnished and Installed	Unit Price
b. Pitless Unit Furnished and Installed	Lump Sum
c. Pressure Testing	Lump Sum

Article 48
Well Grouting

PREAMBLE

Grouting consists of filling an annular or other space with an impervious material. The reasons for grouting are: 1) protection of the aquifer, or aquifers, including the prevention of water movement between aquifers, for purposes of maintaining quality or preserving the hydraulic response of the producing zone(s), and 2) protecting the well against the entry of unwanted water from the surface or a subsurface zone.

A third, and sometimes important purpose of grouting is to protect the casing. This may be necessary to guard against attack by corrosive waters, or where special assurance of structural integrity is desired. A satisfactory grouting program must result in complete envelopment of the casing.

In determining the specific grouting requirements of a well at a designated site, consideration must be given to existing surface conditions, especially the location of sources of pollution, and to subsurface geologic and hydrologic conditions. To protect against contamination or pollution by surface waters or shallow subsurface waters (such as effluent from septic tanks) the annular space shall be sealed to whatever depth is necessary to protect the well. This may be as little as 10 feet or more than 100 feet, depending on conditions.

Formations which yield polluted water or water of an undesirable quality must be adequately sealed off to prevent pollution or contamination of the overlying or underlying waterbearing zones. To accomplish this the annular space shall be grouted from at least 10 feet above to 10 feet below the interval from which such polluted or mineralized water is being produced.

In general, positive emplacement of grout by tremie, pumping, or pressure is strongly recommended for all wells where the grout is to be placed under water or where the void space to be filled is not easily accessible from the surface.

Centralizers may be required in certain zones to prevent the casing from contacting the wall of the bore hole, or to maintain a minimum annular space where a complete seal is imperative.

Where grouting is required the OWNER and/or appropriate regulatory agency should be notified in advance of the work. Prior to grouting the annular space should be flushed to assure that the space is open and ready to receive the sealing material. Grouting should be done in one continuous operation in which the annular space is filled. Where pours exceed 100 feet, the collapse strength of the casing should be checked prior to grouting. Grout containing cement should be entirely placed before the occurrence of the initial set. Again, caution is required in deep seals. It is essential that the grout always be introduced at the bottom of the space being grouted. This is to avoid segregation or bridging of the grout materials and to exclude foreign substances. The grout may be forced into the annular space by suitable pumps or by air or water pressure.

Under certain conditions placement by gravity or by means of dump bailers is practical and satisfactory. Gravity installation without the aid of a tremie or grout pipe should not be used unless the interval to be grouted can be seen clearly and is dry. In no instance should it be done beyond 30 feet of depth. Only by visual observation can there be assurance that grout introduced in this way is properly and uniformly distributed.

Where a tremie pipe is used there should be a minimum annular opening of two inches (5.08 cm) between the outer surface of the inside casing and the inside surface of the external casing or borehole. The minimum size tremie pipe should be one and one-half inches in diameter. Where concrete grout is used the minimum size tremie pipe should be a nominal one and one-half inches in diameter.

The method used shall be optional with the **CONTRACTOR**, provided there is no conflict with requirements for construction practice set forth in these standards. Cement-based materials are the most commonly used grouts. Neat cement (cement and water), sand-cement, and concrete (cement, sand and coarse aggregate) are readily available already mixed or they can be easily mixed at the site. Neat cement and sand cement grouts are effective and permanent sealing materials and are preferred. Concretes are more applicable where the space to be filled is substantial and warrants the saving gained from the use of less cement.

The usefulness of clay as a sealant in well construction is limited to instances where drying out and washing away cannot occur. Clays are usually not suitable as sealants under the following conditions:

1. When sealants will be in contact with aquifers.
2. Wherever structural strength or stability of the sealant is required.
3. Wherever the sealant might dry out.
4. Wherever flowing or moving water might break down the sealant.

For the use of clay in well abandonment operations see Article 86.

There are presently no fool-proof field tests that can be performed to determine if a proper grout seal has been achieved. All five of the most commonly used field tests, e.g., the static water level test, the water temperature test, the water chemical composition test, the pressure test and the cement bond log test, etc., have imperfections. However, under controlled conditions, the latter two tests may indicate in a general way the nature of the grout seal and its probable effectiveness. Considerable research is needed in this area of technology. Suffice it here to state that the proper choice of any field method depends solely on a clear understanding of the specific hydrogeologic conditions and the construction techniques and materials employed in the grouting operation.

It should be noted that in situations where the effectiveness of the grouting procedure is of extreme importance, it is recommended that the grouted zone either be pressure tested or an appropriate cement bond log run. The interpretation of the data from such tests must be made by a log analyst with considerable experience with such data.

GROUTING MATERIALS TO BE USED

48.100–000–000. ***Concrete Grout.*** A mixture of Portland cement (ASTM C150), sand, coarse aggregate and water in the proportion of at least five (5) bags of cement per cubic yard of concrete to not more than seven (7)[*] gallons of clean water per bag of cement (one cubic foot or 94 pounds) shall be used. The use of special cements, bentonite to reduce shrinkage or other admixtures (ASTM C494) to reduce permeability, increase fluidity, and/or control time of set, and the composition of the resultant slurry must be approved by the OWNER or PROJECT REPRESENTATIVE.

48.200–000–000. ***Sand Cement Grout.*** A mixture of Portland Cement (ASTM C150), sand and water in the proportion of not more than two parts by weight of sand to one part of cement with not more than seven (7)[*] gallons of clean water per bag of cement (one cubic foot or 94 pounds) shall be used. The use of special cements, bentonite to reduce shrinkage or other admixtures (ASTM C494) to reduce permeability, increase fluidity, and/or control time of set, and the composition of the resultant slurry must be approved by the OWNER or PROJECT REPRESENTATIVE.

48.300–000–000. ***Neat Cement Grout.*** A mixture of Portland cement (ASTM C150) and not more than seven (7)[*] gallons of clean water per bag (one cubic foot or 94 pounds) of cement, shall be used. The use of special cements, bentonite to reduce shrinkage or other admixtures (ASTM C494) to reduce permeability, increase fluidity, and/or control time of set, and the composition of the resultant slurry must be approved by the OWNER or PROJECT REPRESENTATIVE.

METHODS OF INSTALLATION OF GROUT

48.010–000–000. ***Bailer Dumping.*** Grout material shall be placed by lowering the grout material to the bottom of the hole in a bailer, and dumping (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The bailer shall not be dumped more than one foot from the bottom of the hole, and a time of no more than ten minutes shall elapse between dumps in a single plug. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours.

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[*] EPA recommends not more than 6 gallons of clean water per bag of cement. It should be noted that better flow characteristics can be produced through the use of cement additives, thereby eliminating the weakening effects which may result from the use of excess water.

48.020-000-000. ***Gravity Filling Without Tremie Method.*** Grout material shall be uniformly poured into the annular space without the aid of a tremie or grout pipe (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). This method shall be employed only where the interval to be grouted is clearly visible from the surface and is dry. Maximum allowable depth to bottom of grout interval shall be 30 feet.

48.030-000-000. ***Tremie Method.*** Grout material shall be placed by tremie pouring (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The tremie method shall only be used where there is a minimum annular space of 3 inches (7.62 cm) between the outside surface of the inside casing and the inside surface of either the external casing or the borehole. The minimum size tremie pipe utilized shall be 2 inches (5.08 cm) inside diameter. Where concrete grout is used the minimum size tremie pipe used shall be three inches (7.62 cm) inside diameter. When making a tremie pour, the tremie pipe shall be lowered to the bottom of the zone being grouted, and raised slowly as the grout material is introduced. The tremie pipe shall be kept full continuously from start to finish of the grouting procedure, with the discharge end of the tremie pipe being continuously submerged in the grout until the zone to be grouted is completely filled. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours.

48.040-000-000. ***Positive Placement—Exterior Method.*** Grout material shall be placed by a positive displacement method such as pumping or forced injection by air pressure (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). Grout shall be injected in the annular space between the inner casing and either the outer casing or the borehole. The annular space must be a minimum of 1½ inches (3.81 cm) for sand-and-cement or neat cement grout, and not less than three times the size of the largest coarse aggregate used. The grout pipe shall extend from the surface to the bottom of the zone to be grouted. The grout pipe shall have a minimum inside diameter of one inch for sand-cement or neat cement grout. It shall have a minimum diameter of 1½ inches (3.8 cm) for concrete grout. Grout shall be placed, from bottom to top, in one continuous operation. The grout pipe may be slowly raised as the grout is placed but the discharge end of the grout pipe must be submerged in the emplaced grout at all times until grouting is completed. The grout pipe shall be maintained full, to the surface, at all times until the completion of the grouting of the entire specified zone. In the event of interruption in the grouting operations, the bottom of the pipe should be raised above the grout level and should not be resubmerged until all air and water have been displaced from the grout pipe and the pipe flushed clean with clear water. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type II-minimum 36 hours.

48.050-000-000. ***Positive Placement—Interior Method—Two Plug.*** Grout shall be placed by the two-plug cementing method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The first spacer plug, which shall be a drillable plug such as a plaster-type material, shall then be inserted and the casing capped. A measured volume of grout shall be pumped in which shall be of sufficient quantity to grout the casing in place. The casing shall then be uncapped, the second plug shall be inserted, and the casing recapped. A measured volume of water slightly less than the volume of the casing shall then be pumped into the casing until the second plug is pushed to the bottom of the casing, expelling the grout from the casing up and into the annular space. The water in the casing shall be maintained constant to prevent backflow until the grout has set. Pressure shall be maintained for a minimum of 24 hours or until such time as a sample of the grout indicates a satisfactory set. Cement grout shall be used for this procedure with a minimum annular space thickness of 1½ inches (3.81 cm) completely surrounding the casing. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours. Concrete grout cannot be used with this method.

48.060-000-000. ***Positive Placement—Interior Method—Upper Plug.*** Grout shall be placed by the upper plug casing method (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). A measured quantity of grout, sufficient to grout the casing in place, shall be pumped into the capped casing. Because this grout is in direct contact with the drilling fluid there will be a narrow zone of weak grout between the drilling fluid and the good grout. The casing shall be uncapped, and a drillable plug, constructed of plastic or other suitable material shall be inserted on top of the grout and the casing recapped. A measured volume of water, equal to the volume of the casing, shall be pumped into the casing, forcing the plug to the bottom of the casing and expelling the grout into the annular space surrounding the casing. Utilizing this method the weak grout zone at the interface of grout and drilling fluid will not be located at the critical position at the bottom of the casing. The water in the casing shall be maintained under pressure to prevent back flow until the grout has set. Pressure shall be maintained for a minimum of 24 hours or until such time as a sample of the grout indicates a satisfactory set. Neat cement or sand-cement grout shall be used for this procedure, with a minimum annular space opening of 1½ inches (3.8 cm) completely surrounding the casing. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours. Concrete grout cannot be used with this method.

48.070-000-000. ***Positive Placement—Interior Method—Capped Casing.*** Grout shall be placed by pumping or air pressure injection through the grout pipe installed inside the casing from the casing head to a point 5 feet (1.5 m) above the bottom of the casing (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The grout pipe shall extend airtight, through a sealed cap on the casing head of the well casing. The casing head shall be equipped with a relief valve and the drop pipe shall be equipped at the top with a valve permitting injection. The lower end of the drop pipe and the casing shall be open. Clean water shall be injected down the grout pipe until it returns through the casing head relief valve. The relief valve is then closed and injection of water is continued until it flows from the bore hole *outside* of the casing to be grouted in place. This circulation of water is intended to clean the hole and condition it to better take the grout. Without significant interruption, grout shall be substituted for water and, in a continuous manner, injected down the grout pipe until it returns to the surface outside of the casing. A small amount of water, not to exceed seventeen gallons per hundred lineal feet (30 m) of 2 inch (5.08 cm) droppipe may be used to flush the grout pipe, but pressure shall be maintained constant on the inside of the grout pipe and the inside of the casing until the grout has set. Pressure shall be maintained for at least 24 hours, or until such time as a sample of the grout indicates a satisfactory set. Neat cement or sand-cement grout shall be used for this procedure with a minimum annular space of 1½ inches (3.8 cm) completely surrounding the casing. Curing time before construction may be resumed: Portland Cement Type I-minimum 72 hours; Type III-minimum 36 hours. Concrete grout cannot be used with this method.

48.080-000-000. ***Continuous Injection Method.*** Grout shall be placed by the float shoe continuous injection method, (after water or other drilling fluid has been circulated in the annular space sufficient to clear obstructions). The bottom of the casing shall be fitted with a suitable drillable float shoe equipped with a back pressure valve. Tubing or pipe shall be run to the float shoe to which it shall be connected by a bayonet fitting, left hand thread coupling, or similar release mechanism. Water or other drilling fluid shall be circulated through the tubing and up through the annular space outside the casing. When the annular space is clean and open, grout shall be pumped down the pipe or tubing and forced by continual pumping out into the annular space surrounding the casing. Pumping shall continue until the entire zone to be grouted is filled. The grout pipe shall then be detached from the float shoe and raised to the surface for flushing. After the grout has set the float shoe, back pressure valve, and any concrete plug remaining in the bottom of the casing shall be drilled out. A neat cement or sand-cement grout shall be used for this procedure with a minimum annular space of 1.5 inches completely surrounding the casing. Curing time required before construction may be resumed shall be 72 hours for Type I Portland Cement and 36 hours for Type III. Concrete grout cannot be used with this method.

48.090-000-000. ***Grout Displacement Method.*** The hole shall be filled with the estimated volume of grout required for the purpose intended. The casing fitted at the bottom with a drillable back pressure valve, metal plate, or similar seal shall be lowered through the grout to the bottom of the hole. If necessary to maintain the bottom of the casing at the bottom of the hole, the casing shall be filled with water, or drilling fluid, and in some cases by applying a load on the bottom with drill pipe. The load shall be maintained until the grout has set, after which the bottom plug is drilled out and the well deepened. Use of this method is limited to wells not more than 100 feet in depth.

LOCATION OF GROUT

48.001–000–000. ***Surface Formation Seal.*** The annular space to be grouted, and surrounding the permanent well casing at the upper terminus of the well, shall be not less than a nominal 2 inches. The length of the grout seal shall be whatever is necessary to prevent the entrance of surface water or undesirable subsurface water into the well. In any circumstance, the length of seal shall not be less than the minimum specified in the state or locally applicable construction code.

The entire space to be grouted must be open and available to receive the grout at the time the grouting operation is performed. If a section of larger pipe (conductor pipe) is installed to keep the entire space open (in caving materials), this larger pipe must be removed, as the grout is installed, from the zone where the seal is required.

The effective length of grout seal (for sanitary purposes) shall be that distance measured from the deepest limit of the seal up to the depth of frost penetration. If a pitless adapter or unit is to be installed, the upper limit of the seal shall be one foot below the field connection of the adapter or unit.

48.002–000–000. ***Bottom Seal Grouting.*** Grout shall be placed in the annular space surrounding the bottom of the casing by the method specified. The space shall be grouted to the extent indicated in Figure 1.

48.003–000–000. ***Selected Interval Grouting.*** All zones containing water of unsuitable quality shall be grouted from a point at least 5 feet (1.5 m) below, to a point at least 5 feet (1.5 m) above the unsuitable zone. The annular space surrounding the casing between grouted zones shall be filled with sand or other suitable granular material.

48.004–000–000. ***Continuous Grouting.*** Grout shall be placed in the annular space surrounding the casing by the method specified. Grouting shall be continuous from the bottom of the permanent casing to the land surface; or, where a filter pack has been installed, from the top of the pack (following development) to the land surface; or, where a well screen only has been installed, from a point 5 feet (1.5 m) above the screen to the land surface. When a pitless adapter or unit is to be installed, the grout shall extend from such depth to within one foot of the field connection of the adapter or unit.

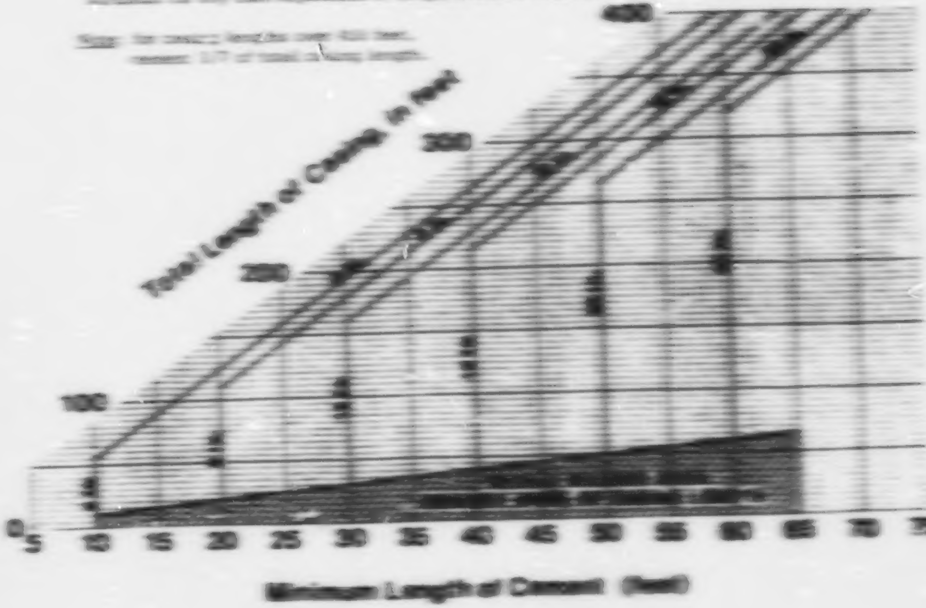
CENTRALIZERS

48.000–100–000. ***Contractor's Choice.***

MINIMUM LENGTHS OF CEMENT
FOR DIFFERENT SIZES AND LENGTHS OF CASING

[illegible]

[illegible]



48.000-200-000. ***Centralizers at Bottom of Hole.*** Centralizers shall be required at the bottom of the casing only.

48.000-300-000. ***Centralizers at Bottom of Hole and other Critical Points.*** Centralizers shall be attached to the bottom of the casing at other critical grouting points such as zones of unsuitable water quality.

48.000-400-000 ***Centralizers at 25 Feet Intervals.*** Centralizers shall be spaced at intervals not greater than 25 feet (7.5 m).

GEOPHYSICAL LOGGING FOR CEMENT BOND

48.000-010-000. ***Acoustic-Sonic Cement Bond Log.*** Upon completion of the cure of the grout, normally 72 hours but varying with materials and additives used, an acoustic-sonic cement bond log shall be run in the borehole from the top to bottom to determine the quality of grout emplacements. The report of this test shall be delivered to the **OWNER** or his representative for his permanent record. The interpretation of such log shall be made by a log analyst of demonstrable experience with such data.

PRESSURE TESTING OF GROUTING SEAL

48.000-001-000. ***Pressure Testing of Grouting Seal.*** Pressure testing of the grout seal shall be employed following the appropriate time for curing of the grout according to all appropriate provisions in this Article. A pressure of 7 to 10 pounds of air per square inch is to be maintained within the well, without the addition of more air, for a period of not less than one hour. Any loss of air shall be construed as indicating a defective seal. To correct such a defect, the **OWNER** shall require the **CONTRACTOR** to make the necessary repairs by re-cementing and pressure testing at 15 psi for one hour.

METHOD OF PAYMENT FOR GROUTING

48.000-000-100. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (48) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (48) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (48) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid.

a. Furnish and Install Grout	Unit Price per Sack
b. Cement Bond Log	Unit Price per Foot
c. Pumping Grout Service	Lump Sum
d. Pressure Testing of Grouting	Lump Sum

Article 49

Well Screens and Perforations

PREAMBLE

In unconsolidated materials, and under certain conditions in consolidated materials, openings must be placed in the lining opposite the water-bearing material to allow the water to flow into the well. At the same time the entrance of fine material during pumping must be prevented or minimized. This is done by developing the well in such a way that the natural, or artificially introduced, coarse-grained materials, in conjunction with appropriate-sized openings, retain the fines while permitting the water to enter without excessive head loss. Thus, there are two basic types of wells in unconsolidated formations, naturally developed well and those with an artificially introduced filter. In normal practice, particularly with domestic wells, natural formations permit the construction of naturally developed wells. In some instances as discussed hereafter, artificial filters are recommended.

During the process of development the finer materials from the aquifer(s) are removed so that only the coarser materials are in contact with the screen. In formations where the materials surrounding the screen are more uniform in grain size and are graded in such a way that the fine grains will not clog the screen, the developed graded materials form what is called a "natural pack". In formations which lack coarse-grained materials and grading is uniform, materials having a grain size coarser than the natural formation are placed around the screen to accomplish this purpose. Such a well is called an artifically packed well or, in many areas, a gravel-packed well (because fine gravels are used for packing).

Artificially packed wells are usually justified when the aquifer is nonhomogeneous, has uniformity coefficient less than 5.0, and has an effective grain size less than 0.01 inch. If aquifers are less than 5 feet (1.5 m) thick and separated vertically by less than 5 feet (1.5 m), the artificial filter should be used providing that more than 5 feet (1.5 m) of screen is required and regardless of the homogeneity or uniformity coefficient of the aquifer formation. Artificial packs are sometimes needed to stabilize well-graded aquifers having a large percentage of fine materials in order to avoid excessive settlement of materials above the screen, where the overlying formations consist of thin beds of fine sand, clay and gravel, or to permit the use of larger screen slots. In addition, in poorly consolidated rock that tends to disintegrate and cave at the time of pumping, an artificial pack may be needed.

To reduce the possibility of corrosion, the well screen and its end fittings should be fabricated of the same material (type 304 Stainless Steel, Silicon Bronze, Silicon Red Brass, Monel 400, Armco Iron, Mild Steel, Plastic, Reinforced Fiberglass, etc.—the choice should be selected on the basis of chemical analysis of the water or prior knowledge of the water quality.) Blank sections used in combination with screens may or may not be of the same material as the screens; however, potential corrosion damage should be considered in such installations.

The well screen aperture openings, screen length and diameter should be selected so as to have sufficient open area to transmit the desired yield with an aperture (slot) entrance velocity equal to or less than 6 feet per minute (0.1 foot per second).

Screen sections are normally joined by welded or threaded connections. If joints are to be welded, the welding rod must be made of material suitable for joining corrosion resistant materials in a manner so as not to reduce that resistance. Where dissimilar metals are joined a dielectric coupling should be used.

The well screen(s) should be set at an elevation, or elevations, in multiple zones, that approximate the best producing zone or zones. The selection of such settings should be based on results of an analysis of the formations penetrated as recorded in the driller's log, stratigraphic log and electric logs (if available).

Screen length should be selected by the following criteria:

A. When the formation being screened is homogeneous and the ground water is under artesian pressure:
    1. If less than 25 feet thick, use a length equal to 70 percent of the formation thickness.
    2. If between 25 feet and 50 feet thick, use a length equal to 75 percent of the formation thickness.
    3. If more than 50 feet thick, use a length equal to 80 percent of the formation thickness.

B. When the formation being screened is *not* homogeneous and ground water is under artesian pressure, select the more permeable sections from:
    1. Laboratory tests of permeability, if representative samples are available.
    2. Sieve analyses.
    3. Geophysical logs.
    4. Visual inspection, if CCTV or photographic coverage of entire interval is available.

C. If the formation being screened is homogeneous and the ground water is unconfined (water table conditions) screen the lower one-third of the formation.

D. If the formation being screened is *not* homogeneous (highly stratified) and is under unconfined conditions, common practice is to select the screen length as one-third the aquifer thickness. The screen is usually set in the lowest, most permeable sand. Tests should be made to establish the location of the most productive zone.

The above rules are designed to obtain the maximum yield from the well. If a lesser yield is specified, such as for a domestic well, for example, use the above rules until enough screen is indicated to obtain an entrance velocity of 6 feet per minute or less.

Six feet per minute (0.1 fps) is a generally accepted value for maximum screen entrance velocity. A lower entrance velocity is recommended for water of significant incrusting potential.

TABLE 11.—*Maximum Screen Entrance Velocities*
(Adapted from Illinois State Water Survey, Bull 49, p. 29)

Coefficient of permeability		Maximum screen entrance velocities[1]		
(gpd/sq ft)	(lpd/m²)	(fpm)	(fps)	(cm/s)
≥6000	≥245,000	≥6	≥0.10	≥3.05
6000	245,000	6	0.10	3.05
5000	204,000	6	0.10	3.05
4000	163,000	6	0.10	3.05
3000	122,000	6	0.10	3.05
2500	102,000	5	0.08	2.54
2000	82,000	5	0.08	2.54
1500	61,000	4	0.07	2.03
1000	41,000	4	0.07	2.03
500	20,000	3	0.05	1.52
≤500	≤20,000	≤3	≤0.05	≤1.52

[1] See *Water Well Technology*, 1974, (3rd printing) published by McGraw-Hill, New York (Chapter 13, Well Hydraulics, pp. 332–336).

FILTER TYPE SELECTION

49.100-000-000. ***Filter Type Selection.*** For a non-homogeneous aquifer, having a uniformity coefficient less than 3.0 and an effective grain size less than 0.01 inches, an artificial filter shall be used as described in Article 50. The uniformity coefficient is the ratio of the sieve size that will retain 40 percent of the aquifer materials to the effective size. The effective size is the sieve size that will retain 90 percent of the aquifer materials.

For non-homogeneous aquifers less than 5 feet (1.5 m) thick and separated vertically by less than 5 feet (1.5 m), the artificial filter will be used as described in Article 50, providing that more than 5 feet (1.5 m) of the screen is required, and regardless of the uniformity coefficient of the aquifer material.

SCREEN TYPE SELECTION

49.010-000-000. ***Contractor's Choice.*** The CONTRACTOR shall select the screen type to be used so that the entrance velocity does not exceed 6 feet per minute (0.1 ft. per second).

49.020-000-000. ***Perforated Pipe.*** After the pipe has been placed in the well, the specified sections shall be perforated by a casing perforator or by shooting. The total area of openings shall be such that the design entrance velocity shall not exceed 6 feet per minute (0.1 foot per second).

Size, i.e. width and length, number, and location of perforations must be reported by the CONTRACTOR on the well log.

49.030-000-000. ***Punched (With Material Removed) and Slotted Pipe.*** The screen shall consist of a pipe that has been punched (with the material removed) or slotted by torch, saw, mill, casting, or other similar means. The slots shall be equal in width as nearly as practical, if slotted, or of uniform spacing and dimensions, if punched. The total area of openings shall be such that the design entrance velocity shall not exceed 6 feet per minute (0.1 foot per second).

49.040-000-000. ***Reinforced Wire Wrapped Punched Pipe.*** The screen shall consist of perforated pipe reinforced with longitudinal bars and wrapped with wire, the wire having a cross section such as to form between each two adjacent loops of wire an opening so shaped as to increase in size as the slot extends inward. The wire will be firmly attached to the bars which are attached to the pipe. The total open area shall be such that the design entrance velocity shall not exceed 6 feet per minute (0.1 foot per second).

49.050-000-000. ***Artifical Filter Screen (Precast).*** The screen shall be constructed by bonding graded silica particles around a slotted core pipe. The total open area shall be such that the entrance velocity of water at the design condition shall not exceed six (6) feet per minute (0.1 foot per second).

49.060-000-000. ***Louvered Pipe.*** The screen shall consist of a pipe that has punched openings in it where material has not been removed. The openings formed shall be between the corner of the outside of the pipe and the punched-out area, and the corner of the inside of the punched portion and its side. The openings shall be uniform and their total area shall be such that the entrance velocity at the design condition shall not exceed 6 feet per minute (0.1 foot per second).

49.070-000-000. ***Continuous Slot Wire Wound Screen.*** The screen shall be constructed of wound wire, reinforced with longitudinal bars, the bars having a cross section that will form an opening between each adjacent coil of wire that is shaped in such a manner as to increase in size inward. The wire shall be firmly attached to the bars which will, in turn, be attached to a coupling adapter. The total open area shall be such that the entrance velocity at the design condition shall not exceed 6 feet per minute (0.1 foot per second).

Screen Aperature Size

†49.001-000-000. ***Contractor's Choice.*** The screen aperture size shall be the responsibility of the CONTRACTOR where there is a guarantee of yield except that the entrance velocity shall not exceed ________ feet (________ m) per minute.

49.002-000-000. ***Aperture Size Selection Criteria.*** The screen aperature size shall be based on the following criteria.

A. Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by an essentially non-caving formation, the aperture size shall be that which retains 30 percent of the aquifer sample.

B. Where the uniformity coefficient of the aquifer is greater than 6 and the aquifer is overlain by a readily caving formation, the aperture size shall be that which retains 50 percent of the aquifer sample.

C. Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by an essentially non-caving formation, the aperture size shall be that which retains 40 percent of the aquifer sample.

D. Where the uniformity coefficient of the aquifer is 3 or lower and the aquifer is overlain by a caving formation, the aperture size shall be that which retains 60 percent of the aquifer sample.

E. For conditions between the extremes listed, the CONTRACTOR shall interpolate to obtain the proper screen aperture size.

F. Where a formation to be screened has layers of differing grain sizes and gradations, use the following rule: If the 50 percent size of the coarsest layer is less than 4 times the 50 percent size of the finest layer, the aperture size shall be selected on the basis of the finest layer, or for each specific layer as indicated in A, B, C, D, or E.

G. If the water is corrosive or the accuracy of the chemical analysis is in doubt, select an aperture size that will retain 10 percent more than is indicated in the above paragraphs.

H. Where fine sand overlies coarse sand, use the fine sand size aperture for the top two feet (61 cm) of the underlying coarse sand. The coarse size aperture shall not be larger than twice the fine sand size.

I. Where an artificial filter is to be used the aperture size selection criteria shall be in accordance with Article 50.002–000–000.

SCREEN LENGTH

49.000–100–000. *Contractor's Choice.* The CONTRACTOR shall select the screen length and interval to be screened provided, however, that the resulting average calculated entrance velocity at the design pumping rate shall not exceed 6 feet per minute (0.1 foot per second).

49.000–200–000. *Screen Selection Criteria.* The length of the screen for an artesian aquifer shall be such that at least 80 percent of the aquifer is screened. The screen shall be centered in the aquifer. The length of the screen for a water table aquifer shall be between 1/3 and 1/2 of the aquifer thickness. The screen should be positioned in the lower 1/3 or 1/2 of the aquifer. In no instance shall the well screen entrance velocity exceed 0.1 foot per second (Aquifer thickness as used here is the total thickness of the sand formation to be screened or, where geophysical logs indicate a specific water-bearing zone, the term refers to the total thickness of the sand formation as indicated by the geophysical log.) For any specified discharge screen of sufficient length shall be installed to obtain an entrance velocity not exceeding 5 feet per minute (0.1 foot per second).

METHOD OF SCREEN INSTALLATION

49.000-010-000. ***Contractor's Choice.*** The screen shall be installed according to the method deemed appropriate by the CONTRACTOR.

49.000-020-000. ***Driven Well Point Method.*** The well point screen shall be attached to the casing and driven into the aquifer.

49.000-030-000. ***Washing Method.*** The screen shall be fitted with a self-closing valve on the bottom. Next, the screen shall be attached to the well casing. A smaller pipe shall then be placed in the screen and by a method selected by the CONTRACTOR also fitted to the self-closing valve. The screen with its casing shall then be "washed" into place by pumping drilling fluid through the inner pipe.

49.000-040-000. ***Pull Back Method.*** The well casing shall be carried through the formation to be screened and cleaned out to the level where the bottom of the screen is to be placed. The screen shall then be lowered to that level by means of a cable attached by a hook to the bail in the bottom of the screen, or by attaching a pipe to a threaded fitting in the bottom of the screen, and lowering the pipe with the screen. The screen can also be placed by gravity under conditions that limit the rate of descent. After the screen is in its proper location, a heavy steel bar or line of pipe may be set on the screen bottom to hold it down and the casing shall be raised until the screen is exposed to the aquifer with the packer, or seal lapped 12 inches (30 cm) into the casing. If a lead packer is used with a telescope-sized screen, it shall then be swedged against the casing until it makes a water-tight seal.

49.000-050-000. ***Driven Through Casing Method.*** The casing shall be set at a level immediately above the top of the formation or portion of the formation to be screened. A well point screen shall be lowered through the casing to the top of the formation by a cable and hook or an attached string of pipe. The screen shall then be seated in the formation by driving it to the desired depth and sealing it to the casing.

49.000-060-000. ***Bailed Through Casing Method.*** The casing shall be placed at a level immediately above the top of the formation or portion of the formation to be screened. A piece of plain tubing of the same material as the screen and several feet long shall be attached to the bottom of the screen. A similar piece, long enough to lap 3 feet (1 m.) into the casing, and a packer shall be attached to the top of the screen. The screen and attachments shall then be lowered through the casing to the top of the formation by cable and hook or an attached string of pipe. The screen shall then be put into place by bailing the aquifer material out from under it and allowing it to settle. After the screen is in place, it shall be sealed to the casing and the bottom tubing plugged.

49.000-070-000. ***Bailed or Air Jetted Through Casing Method.*** The casing shall be placed at a level immediately above the top of the formation or portion of the formation to be screened. A bail-down shoe shall be attached to the screen and a line of bail-down pipe attached to the shoe by a right and left-hand coupling, or similar release device. The screen shall then be lowered by the bail-down pipe to the top of the aquifer and then bailed into place or seated by blowing air through the bail-down pipe. When the screen has reached the desired depth, the bail-down shoe shall be plugged at the bottom by an approved method, and the screen shall be sealed to the casing.

49.000-080-000. ***Washed Through Casing Method.*** The casing shall be placed at a level immediately above the top of the formation to be screened. The screen shall be fitted with a self-closing valve at the bottom and a small inner pipe attached to the valve. The screen shall be lowered through the casing by any means deemed appropriate. The screen shall be washed into place by pumping drilling fluid through the inner pipe. It shall then be sealed to the casing.

49.000-090-000. ***Suspended From Surface Method.*** The screen, with closed bottom, shall be attached by an approved manner to the casing and lowered into the well with the casing. In no instance shall it be driven or forced. It shall remain suspended from the surface until the formation has collapsed against it or until a filter material or formation stabilizer has been added.

METHOD OF JOINING SCREEN TO SCREEN

49.000-001-000. ***Joining.*** Screen sections for a single interval shall be joined by threaded and coupled joints, socket-type fittings and solvent welding, or electric arc or acetylene welding. Welding rods and methods recommended by the screen manufacturer shall be employed. Resulting joint(s) must be straight, sand tight and retain 100 percent of the screen strength.

Blank spacers for multiple interval screen shall be of the same material as the casing, unless otherwise specified. They shall be joined to the screen by the threaded and coupled joints, socket-type fittings and solvent welding, or electric arc or acetylene welding using materials and procedures specified in Article 47.001-000-000. The resulting joints must be straight, sand tight and retain 100 percent of the screen strength.

METHOD OF CONNECTING SCREEN TO CASING

49.000-000-100. ***Neoprene or Rubber Seal.*** A neoprene or rubber seal especially made for this purpose shall be attached to the top of the screen. It shall be designed to be self-sealing in the well casing.

49.000-000-200. ***Lead Packer.*** A lead packer especially made for this purpose shall be attached to the top of the screen. After the screen is in place, the lead shall be expanded at its top to make a sand tight seal with the well casing.

49.000-000-500. ***Cement Fill in Annulus.*** The casing shall be joined to a pipe extending above and attached to the screen by filling the space between them with neat cement for a vertical distance of 3 feet (1 m) and at least 1 inch (2.5 cm) thick.

49.000-000-600. ***Threaded, Coupled, Welded Joints.*** The casing and screen shall be joined by threaded and coupled joints, socket fitting and solvent welding, or electric arc or acetylene welding using materials and procedures specified in Article 47. 001-000-000. The resulting joints must be straight, sand tight and retain 100 percent of the screen strength.

Methods of Sealing Bottom

49.000-000-010. ***Lead Method.*** If lead shot is used, the bottom of the deepest screen shall be sealed by installing an eight (8) inch layer of number eight (8) lead shot in the bottom of the screen. If lead wool is used, the bottom of the deepest screen shall be sealed by placing lead wool in the bottom of the screen and tamping it to form a four (4) inch layer, sealing the bottom.

49.000-000-020. ***Bag Cement Method.*** A pipe extension at least 4 nominal diameters in length shall be attached to the bottom of the deepest screen (the drill hole having been deepened to accommodate the extension). The bottom shall then be sealed by lowering into the extension pipe sufficient dry cement in small cloth bags to fill it to a depth of at least 3 nominal diameters, packing it firmly into place.

49.000-000-030. ***Self-Closing Valve Method.*** The bottom of the deepest screen shall be sealed by means of a self-closing valve on the bottom of the screen.

49.000-000-040. ***Fabricated Plug Method.*** The bottom of the deepest screen shall be sealed with a threaded or welded plug or point made of the same material as the screen body.

49.000-000-050. ***Welded Plate Method (Casing Material).*** The bottom of the deepest screen shall be closed by welding to it a plate of the same material as the casing and of the same thickness.

49.000-000-060. ***Welded Plate Method (Screen Material).*** The bottom of the deepest screen shall have a plate of the same material as the screen welded to it to seal it.

Method of Payment for Well Screens

49.000-000-001. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (49) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (49) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (49) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price percent of add-on bid.

a. Screen, or Perforated Casing Furnished and
Installed .... Unit Price/Foot

Article 50
Well Filter Construction (Artificial)

PREAMBLE

A filter pack (gravel pack) consists of a clean sand or gravel of selected grain size and gradation which is installed in the annular space between the screen and the wall of the well bore. The filter has a larger average grain size and usually a smaller coefficient of uniformity than the aquifer material. This permits use of a larger screen slot size and consequent larger open area so that entrance velocity is lowered and head losses to the well are reduced. The filter has a considerably higher permeability than the formation so that the effective diameter of the well is increased to some extent. Both these factors tend to increase the efficiency and specific capacity of a well and tend to reduce the possibility of excess sand production.

The grain size and gradation of the filter are selected to stabilize the aquifer material and to permit only the fine fractions to move into the well during development. Thus after development a correctly filtered well is relatively sand-free, and a narrow annulus of the formation adjacent to the filter has its permeability increased to some degree.

Generally, the thinner the filter the better. Actually a correctly designed filter ½-inch thick would be adequate, but the mechanical difficulties of satisfactorily placing such a filter preclude its use. From a practical standpoint, filter packs are usually about 4 to 8 inches (10 to 20 cm) thick.

In a shallow well with 6 inches or more of annular space and 5 or 6 feet (1.5 or 1.8 m) of screen the filter material can be easily dumped in to give a satisfactory installation. In deep wells with longer screens, to avoid bridging and segregation of the filter material, it should be placed with great care. If placed by gravity the material should be introduced at a metered, uniform rate. Frequently it is placed via a tremie pipe. Other practices include washing or pumping the filter material in with water (as a slurry) which is an effective way of placing the filter pack. Once installation of the filter material is started it should proceed at a uniform rate until completed from the bottom of the well to a selected point above the screen or perforations.

The filter pack should consist of clean, well-rounded grains that are smooth and uniform. The filter should be siliceous with a limit of 5 percent by weight of calcareous material. The filter should be obtained from an approved source and should consist of hard, rounded particles with an average specific gravity of not less than 2.5. Not more than 1 percent by weight of the material should have a specific gravity of 2.25 or less. The filter should contain not more than 2 percent by weight of thin, flat or elongated pieces (pieces in which the largest dimension exceeds three times the smallest dimension) determined by hand picking; and should be free of shale, mica, clay, sand, dirt, loam, and organic impurities of any kind and should contain no iron or manganese in a form or quantity that will adversely affect the water quality. Samples of the filter to be furnished should be submitted for approval by the supplier before shipment.

Samples of filter material, including sieve analysis, shall be submitted to the **OWNER** for approval in advance of delivery and placement. The filter material should be delivered to the site upon approval of same by the **OWNER**. Suitable storage area for the gravel should be provided by the **CONTRACTOR**. The gravel may be delivered, bagged and stacked at the site or it may be delivered in bulk. If delivered in bulk it should be placed on a protective sheet preventing contact between it and the ground. It should be protected from the elements by a suitable covering.

The **OWNER** or the **PROJECT REPRESENTATIVE** should obtain two grab samples from each load of filter material delivered and carry out or have carried out by others a mechanical analysis of these samples to determine that the filter material complies with the grain size and uniformity specified.

If more than one grade of filter material is to be installed in the well simultaneously, the grades of gravel should be mixed at the surface before introduction into the well. Mixing is the responsibility of the **CONTRACTOR**; however, the **OWNER** or **PROJECT REPRESENTATIVE** should approve a suitable method prior to the **CONTRACTOR'S** commencement of mixing operations. Regardless of the method of mixing used, there must be no chance of contamination of the filter material during mixing. The annular space between the well screen and the wall of the hole should be filled with clean, disinfected, selected gravel to form a bed around the well screen. This filter bed should be graded from fine to coarse as conditions may require. The filter material should be introduced through pipes or by a method approved by the **OWNER** or his agent where the filter material is installed directly into the open hole. Every precaution should be taken which will insure the proper placing of the filter material continuously from the bottom of the well to a point above the well screen without separation of the materials as they are introduced into the well.

When placing a filter in a well, care must be taken to assure that any filter material that enters the well screen during placement is removed during development.

Filter-Type Selection

50.100-000-000. ***General Criteria.*** If the formation is non-homogeneous, has a uniformity coefficient greater than 3.0, and has an effective grain greater than 0.001 inches, a natural filter shall be used.

FILTER CONSTRUCTION STANDARDS

50.010-000-000. ***General.*** For standards on Screen/Type Selection, Screen Length, Method of Installation, Method of Joining, Method of Sealing Screen Position and Payment for these services Article 40 shall apply.

SELECTION OF FILTER GRAIN SIZE AND SCREEN APERTURE SIZE

50.001-000-000. ***Contractor's Choice.*** Selection of the filter grain size shall be the CONTRACTOR'S responsibility.

50.002-000-000. ***Selection Criteria.*** The filter grain size shall be determined by taking the 70 percent retained grain size of the finest formation to be filtered and multiplying it by 4, 5, or 6. This is the 70 percent retained grain size of the filter material to be used. The uniformity coefficient (the size of sieve that retains 40 percent of the sample divided by the size that retains 90 percent) shall not be greater than 2.5. The gradation of the filter material shall form a smooth and gradual size distribution curve when plotted. The screen aperture openings shall be of such size as to retain between 85 and 100 percent of the filter material. The thickness of the filter shall range from a minimum of 3 inches (10 cm) to approximately 8 inches (20 cm).

LENGTH OF ARTIFICIAL FILTER

50.000-100-000. The filter material shall extend a distance equal 2½ times the largest diameter of the well above any screen. Sand, cement, or additional filter material shall be placed between the filter material and the lower limit of the sanitary seal, according to state and local regulations. The size of the sand shall be such that it will not infiltrate into the filter material.

50.000-200-000. The filter material shall extend from a point equal in distance to 2½ times the largest diameter of the well below the lowest screen to the same distance above the highest screen. Sand, cement, or additional filter material shall be placed between the filter material and the lower limit of the sanitary seal, according to state and local regulations. The size of the sand shall be such that it will not infiltrate into the filter material.

50.000-300-000. The filter material shall extend from a point equal in distance to 2½ times the largest diameter of the well below the lowest screen to a point 50 feet (15 m) above the lower end of the outer, or surface, casing where well depth permits.

50.000-400-000. The filter shall extend from a point equal in distance 2½ times the largest diameter of the well below the lowest screen to the land surface. Suitable accompanying well design features will include (1) filter zone in the upper section of the well will be surrounded with casing and (2) cemented into place via the provisions applicable in Articles 47 and 40 to insure a sanitary seal.

Storage of Filter Material

50.000-010-000. ***Bulk Delivery—Open Storage.*** The filter material shall be delivered in bulk and stored on the bare ground. The layer of filter material in contact with the ground shall not be used.

50.000-020-000. ***Bulk Delivery—Covered Storage.*** The filter material shall be delivered in bulk and stored on a surface covered with a clean material such as plastic or canvas. The filter material shall be covered in a similar manner to prevent any contamination of its surface.

50.000-030-000. ***Bagged Delivery.*** The filter material shall be delivered in bags and shall be protected from the weather and contamination until used.

Disinfection of Filter Material

50.000-001-000. ***Disinfection.*** The CONTRACTOR shall be responsible for insuring that the filter material is adequately disinfected during installation, particularly if the well is to be used for domestic purposes or as a public water supply. Procedures for disinfecting the material shall be in accordance with Article 54.

Method of Installation of Filter Material

50.000-000-100. ***Poured.*** The filter material shall be poured in the annular space between the borehole wall and the casing attached to the screen at a measured and uniform rate.

50.000-000-200. ***Poured with fluid.*** The filter material shall be poured into the annular space between the borehole wall and the casing attached to the screen. Water or drilling fluid shall be pumped through the inner casing at the same time and allowed to flow upward on the outside of the inner casing.

50.000-000-300. ***Tremie Placed.*** The filter material shall be placed by the use of a tremie pipe lowered to the bottom of the space to be packed and slowly raised as the filter material fills the annular space. As the filter material is poured into the tremie pipe, water shall also be poured in to help carry the filter material.

50.000-000-400. ***Tremie Placed with Fluid.*** The filter shall be placed by the use of a tremie pipe lowered to the bottom of the space to be packed and slowly raised as the filter is placed. Water or thin drilling fluid shall be pumped from the inner casing and allowed to flow into or be pumped in with the filter material.

50.000-000-500. ***Tremie with Ell.*** A tremie pipe with an ell formed on its bottom to direct its discharge perpendicular to the long axis of the screen shall be lowered to the bottom of the space to be packed and the filter shall be placed by pumping water or drilling fluid through the tremie pipe with the filter material being added to the fluid being pumped. Pressure shall be maintained that will keep the filter material in suspension in the annulus. The tremie shall be gradually raised as the pack is injected.

50.000-000-600. ***Crossover Tool.*** The filter material shall be placed by pumping it to a point above the screen through a "cross-over" tool and then allowed to fall as the drilling fluid is circulated through the bottom of the screen via an inner removable pipe.

METHOD OF PAYMENT
FOR ARTIFICIAL WELL FILTER

50.000-000-010. *Method of Payment.*

Option A (Lump Sum): All of the work performed under this Article (50) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (50) shall be paid for on the basis of price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (50) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

a. Artificial Well Filter Furnished and Installed . . . Unit Price/Foot
b. Filter material . . . . Unit Price /Cu. Yd.

Article 51
Well Plumbness and Alignment

PREAMBLE

Plumbness and alignment of a well are never perfect. In relatively shallow holes, particularly those where the smallest inside diameter of the well is considerably larger than the maximum outside diameter of pumping equipment in the well, some deviation in plumbness and alignment seldom causes serious problems. The **CONTRACTOR** can keep alignment within practical limits by exercising reasonable care under most conditions. Plumbness and alignment become critical on deep holes and/or where a vertical turbine pump is to be permanently installed in the well. Manufacturers of turbine pumps state that their pumps will operate satisfactorily when considerably inclined from the vertical. However, a well badly out of alignment and containing kinks, bends, or corkscrews should be rejected because such deviations cause severe wear on the pump shaft, bearings and discharge casings and under extreme conditions might make it impossible to get a pump into or out of the well. Conditions that cause wells to become crooked or out of plumb include the nature of the material penetrated while drilling, trueness of well casing, tension of cable tool drilling line, and pull-down force on drill pipe in rotary drilling. Solutions for the problems vary as widely as do the conditions which cause the problems.

METHODS OF TESTING

51.100-000-000. *Plumbness and Alignment Test.* The completed well shall be sufficiently plumb and straight so that there will be no interference with installation, alignment, operation or future removal of the permanent well pump.

~~§51.200-000-000~~. ***Plumbness and Alignment Test.*** All wells should be constructed and all casings and liners set round, plumb, and true to line as defined herein. To demonstrate the compliance of the work with the requirements, the CONTRACTOR shall furnish all labor, tools and equipment and perform the test or tests described herein. The test for plumbness and alignment shall be made following construction of the well, and before test pump equipment is installed.

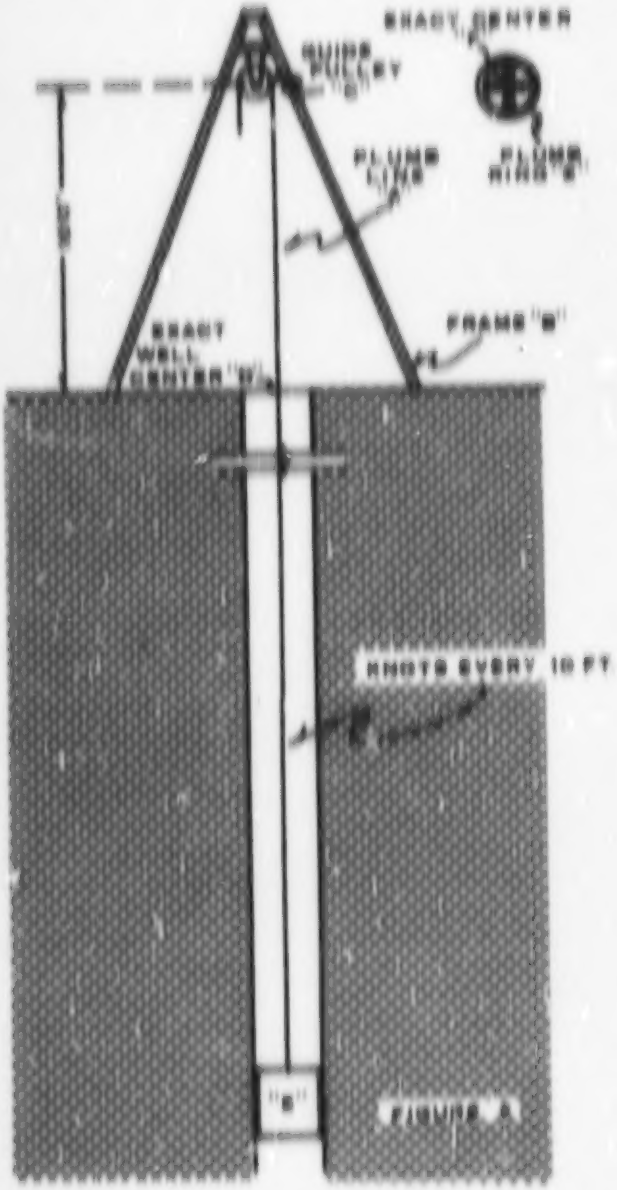
Alignment shall be tested by lowering into the well to a depth of at least ________ feet (lowest anticipated pump setting) a section of pipe 40 feet (12 m) long or a dummy of the same length. The outer diameter of the pipe or dummy shall be not more than ½ inch (1.3 cm) smaller than the inside diameter of that part of the casing or hole being tested when the casing diameter is a nominal 10 inches (25 cm) or less. When the nominal diameter of the casing being tested is 12 inches (30 cm) or greater, the outer diameter of the test pipe or dummy shall not be more than 1 inch (2.5 cm) smaller than the inside diameter of that part of the casing or hole being tested. The dummy when lowered into the casing shall pass freely the entire depth of the well.

The test for plumbness shall be made with a plummet. Construct a tripod or frame "B" similar to that shown in Figure 3. The center of the pulley "C" should be exactly 10 feet above the top of the well. The pulley must be so located that the plumb line "A" will come off its outer edge exactly over the center "D" of the well casing.

Make the plumb ring or plunger "E" ¼ inch smaller in diameter than the inside diameter of the well casing. It can be made from a piece of sheet steel or a short piece of pipe. Whichever is used, it must be heavy enough to keep the plumb line taut. The hub of the ring must not be solid as the water must pass through it as it is lowered in the well. The hole "F" through which the plumb line "A" passes must be in the exact center of the ring. Knots or marks should be made every 10 feet on the plumb line, to indicate the depth the ring has been lowered in the well.

The well characteristics are determined by lowering the plumb ring 10 feet at a time and taking a reading at each location. If the plumb line passes exactly through the center line "D" at any location, the well is plumb at the depth the plumb ring is suspended. However, if the line "A" does not pass through "D", the well at that depth is out of plumb by an amount equal to distance "A" from "D" plus an equal distance for each 10 feet that the plumb ring "E" is below the floor level. For example, assume that "C" is exactly 10 feet above floor level and "D" is at floor level. If plumb line "A" is 1/16th of an inch from the center line of the well at "D" and the plumb ring "E" is 10 feet below the floor line, then the well is 1/8th of an inch out of plumb at the 10 foot level. If "A" is 1/16th inch from the center of the well at "D" when the plumb ring "E" is 50

Figure 2.
Well Plumbness Test Assembly


EXACT CENTER
GUIDE PULLEY "C"
PLUMB LINE
PLUMB RING "E"
EXACT WELL CENTER "D"
FRAME "B"
KNOTS EVERY 10 FT
"E"
FIGURE A

feet below the floor line at "D". Then the well is 1/16th plus 5/16ths, or 3/8ths of an inch out of plumb at the 60 foot level. This is simply the proportion of similar triangles, and expressed in that way, variation from plumb equals,

$$\frac{60\text{ ft.}}{10\text{ ft.}} = \frac{1}{16} \times \frac{6}{16} = \frac{3}{8}$$

This reading at the various depths tested may be plotted on cross section paper and an accurate diagram of the well developed.

Should the plumb or dummy fail to move freely through the specified length of casing or hole, or should the well vary from the vertical in excess of two-thirds of the smallest inside diameter of that part of the well being tested per 100 feet (30.48 m) of depth, the plumbness and alignment of the well shall be corrected by the **CONTRACTOR** at his own expense. Records of deflection readings and all other pertinent information shall be kept and made a part of the permanent well log and record.

Should the **CONTRACTOR** fail to correct the faulty alignment and plumbness, the **OWNER** or his Representative may refuse to accept the well. The **OWNER** or his representative may modify the requirements for plumbness in this Article if in his judgment (a) the **CONTRACTOR** has exercised all possible care in construction of the well and the defect is due to circumstances beyond his control; (b) the utility of the completed well will not be materially affected; or (c) the cost of necessary remedial measures will be excessive. In no event will the provisions of this paragraph with respect to alignment be waived when it is anticipated that the well will be pumped with a line-shaft turbine pump.

81.300-000-000. ***Drift Indicator Survey.*** A mechanical drift indicator shall be run in the hole and the drift determined at intervals of 50 feet (15.24 m) of depth to the total depth of the hole. If a deflection of less than one degree is indicated, the well shall be deemed in proper plumbness and alignment. If any reading taken indicates a deflection from vertical exceeding one degree, the **CONTRACTOR** shall immediately notify the **OWNER** or his representative. The mechanical drift indicator surveys taken to and including that point shall be analyzed by the **CONTRACTOR** and the **OWNER** and, if in the opinion of the **OWNER** or his representative the alignment is not acceptable the **CONTRACTOR** will be required to correct the alignment or abandon and plug the hole as directed by the **OWNER**, and to drill at his expense another hole. Upon completion of the hole or at any time prior thereto, in case of disagreement between the **CONTRACTOR** and the **OWNER** as to the mechanical drift, indicator disc interpretations, the mechanical drift indicator discs shall be analyzed by a service company and two copies of the service company's interpretation of the survey shall be supplied to the **OWNER**. This interpretation shall be binding on both parties. The selection of the service company making the interpretation shall be by agreement of both the OWNER or CONTRACTOR.

Records of deflection readings and all other pertinent information shall be kept and made part of the permanent well log and record. The OWNER may modify the requirements for plumbness in this Article if in his judgment (a) the CONTRACTOR has exercised all possible care in constructing the well and the defect is due to circumstances beyond his control; (b) the utility of the completed well will not be materially affected; or (c) the cost of necessary remedial measures will be excessive.

METHOD OF PAYMENT
FOR WELL PLUMBNESS AND ALIGNMENT

51.010-000-000. *Method of Payment.*

Option A (Lump Sum): All of the work performed under this Article (51) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (51) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (51) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

a. Plumbness and Alignment	Lump Sum/Test
b. Drift Indicator	Lump Sum/Test

Article 52
Well Development

PREAMBLE

Proper well development can sometimes make a poor well into a good one. Without proper development an otherwise excellent well may never be satisfactory. Proper development will improve almost any well regardless of type or size, and only under unusual circumstances or because of improper methods will it do harm. Practically all methods of drilling cause compaction of unconsolidated materials in an annulus of variable thickness about a drill hole. In addition, fines are driven into the wall of the hole, drilling mud invasion may occur to a greater or less extent, and a mud cake may form on the wall of the hole. In consolidated formations similar compaction may occur in some poorly cemented rocks, where cuttings, fines and mud are forced into fractures, bedding planes and other openings, and a mud cake forms on the wall of the hole. All of these conditions reduce the permeability of the formation adjacent to the well and act to reduce the yield and increase the draw-down.

Proper well development breaks down the compacted borehole wall, liquefies jelled mud, and draws it and other fines which have penetrated the aquifer or were initially present in it into the well, from which they are removed by bailing or pumping. This creates a more permeable and stable zone about the screen. This stabilization of the formation adjacent to the well screen practically eliminates sand pumping, and contributes to a more efficient well, longer well life, and reduced operation and maintenance costs.

Numerous methods of development are available and the literature contains considerable discussion of the suitability of each method in various types of formations. An important factor in any method is that the development work be started slowly and gently and increased in vigor as the well is developed. All but one method of well development require the application of sufficient energy to disturb the natural formation or filter pack so as to free the fines and allow them to be drawn into the well, and to cause the coarser fractions to settle around and stabilize the screen. This is usually accomplished by the surging of water into and out of the well and the formation. The exception is hydraulic jetting, which depends upon a high velocity water jet discharging through the screen. The jets disturb both the filter and formation and the water, following the path of least resistance, returns to the well above and below the jets, carrying the fines into the well.

Determination of the adequacy of development is largely a matter of experience and judgment but as a general rule if interrupted overpumping or rawhiding is used as a final method of development the degree of development can be estimated from sand samples caught in an Imhoff cone or by other methods on each resumption of pumping. On initiation of interrupted pumping, samples should be caught as frequently as possible as soon as discharge starts at each new rate of pumping. Sampling of this type at each rate of discharge will show the time required for maximum sand content to occur and will serve as a guide to subsequent sampling and development.

Shortly after the period in which maximum sand content occurs in the discharge for each new rate of pumping, the discharge will become practically sand free until the well is again surged. As rawhiding continues, the amount of sand at the maximum will decrease and the time in each discharge interval until water of low sand content is discharged becomes shorter.

The more commonly used methods of well development are listed as follows:

A. Pumping
B. Surging
  a. Valved Surge Device
  b. Solid Surge Device

        c. Pumping with Surge Device
        d. Air Surge
    C. Fracturing
        a. Explosives
        b. High Pressure Fluid Injection
    D. Washing
        a. High Pressure Jetting
        b. Backwashing

Requests for bids on a lump sum basis for development may result in unsatisfactory work. It is practically impossible to anticipate how a well will respond to development and how long it will take to achieve adequate development. It is better to provide for development on a unit price per hour basis and continue development until the desired sand content at the design discharge are achieved.

The casing and screen diameters, length of screen and character of the formation are determining factors in the selection of applicable methods of well development. The following paragraphs apply to the most commonly used methods summarized above for various types and sizes of wells. That all methods are not covered does not signify that those omitted are not satisfactory but only that they are less commonly used or are of limited applicable.

Testing For Sand In Water

One method of growing popularity is the Centrifugal Sand Sampler. Water enters the body of the device at a tangent immediately below the baffle. Any sand present will fall to the bottom of the centrifuge tube. The flow is maintained at a constant value, independent of inlet pressure via a flow-control valve this is rated at 0.5 GPM. The sand content can be computed since the flow through the tester is known.

PUMPING OR BAILING METHOD

52.100-000-000. *Continuous Overpumping.* The development process shall include development by uninterrupted pumping at pumping rates up to 1½ times the design capacity.

52.200-000-000. *Interrupted Overpumping.* The development process shall include development by interrupted pumping. The pumping shall be done with a pump capable of pumping at rates up to 2 times the design capacity. The pumping should be carried out in at least 5 steps. These steps should include pumping rates of ¼, ½, 1, 1½ and 2 times the design capacity, with no check valve nor foot valve present. Pumping shall be conducted in 5 minute cycles, and shall continue a minimum of 2 hours or until such time as acceptable standards are attained.

52.300-000-000. *Surging and Bailing (Utilizing Bailer).* The development process shall include surging and bailing the well. The surging shall be accomplished by utilizing the bailer as a surging device. If fines have been drawn into the well and have settled on the bottom and accumulated to a depth where they block 10 percent or more of the total screen length, the well shall be bailed or otherwise cleaned to the bottom before resumption of surging. On completion of development the well shall be cleaned to the bottom.

52.400–000–000. ***Surging and Bailing (Utilizing Surge Block).*** The development process shall be carried out by surging and bailing the well. The surging shall be done by a single or double solid (or valved) surge block. Surging shall start at the bottom of the lowest screen in the well and proceed upwards.

Mechanical Surging and Pumping Method

52.010–000–000. ***Surging and Pumping.*** The development process shall include surging and pumping the well. The surging shall be done by either a solid or valved surge block. The pumping shall be done through the surge block which incorporates a piece of the suction pipe in the fabrication of the block. Pumping shall be done simultaneously with the surging at rates up to ½ of the design capacity. Fines drawn into the well shall be pumped out periodically before such accumulation reaches 10 percent of the screen length. Upon completion of the development work the well shall be cleaned to the bottom.

Hydraulic Jetting Method

52.001–000–000. ***Hydraulic Jetting.*** Development shall be accomplished by simultaneous high-velocity, horizontal-jetting and pumping. The outside diameter of the jetting tool shall be one inch less in diameter than the screen inside diameter. The minimum exit velocity of the jetting fluid at the jet nozzle shall be 150 ft./sec. The tool shall be rotated at a speed less than one rpm. It shall be positioned at one level for not less than two minutes and then shall be moved to the next level which shall be no more than 6 inches vertically from the preceding jetting level. The jetting shall proceed from the bottom of the screen to the top. Pumping from the well shall be at a rate of 5 to 15 percent more than the rate at which water is introduced through the jetting tool. Water to be used for jetting must contain less than 1 ppm suspended solids.

Air Development Method

52.000–100–000. ***Single Pipe System Open to Atmosphere.*** Development shall be done by the utilization of a single pipe air pumping system using the casing or the bore hole itself as the eductor line. The compressors, air lines, hoses, fittings, etc. shall be of adequate size to pump the well by the air lift principle at 1½ to 2 times the design capacity of the well. The CONTRACTOR shall initially pump the well with air until the well is developed to the point that it yields clear, sand-free water. He shall then shut off the air and allow water in the well to return to a static condition. He shall then reopen the valve and reintroduce air into the well until water is again brought to the surface by the air lift, at which time he will close the air valve and allow the water to drop back down the well and return to a static condition. He shall repeat this lifting and dropping of the column of water until the water in the well becomes turbid at which time he will continuously pump the well with air until it again yields clear sand-free water. The CONTRACTOR shall repeat the above operations until the well no longer produces fine material when it is surged and backwashed as described above.

The bottom of the air line shall be placed at different levels in order to facilitate development of all intake areas and multiple water producing zones, and the process repeated until all zones yield water free of turbidity when surged and backwashed.

52.000-200-000. ***Single Pipe System Closed to Atmosphere.*** The CONTRACTOR shall install a suitable valve on the discharge line leading from the top of the casing, secure the air line into blowing tee or ell affixed to a valved air connection on the top of the casing. He shall then close the valve on the discharge line, attach the air hose to the valved fitting and introduce air into the well, forcing the column of water in the well down. Care shall be exercised to prevent air from entering the water-bearing formation. This shall be accomplished by the installation of a separate pipe, open to the atmosphere at the top, and installed in the well to a point ten feet above the water-bearing zone. When the water level in the well is forced down to the bottom of this air release pipe, the discharge valve shall be opened and the water allowed to rise back to the static level. This procedure may be repeated and/or alternated with the "Single Pipe System Open to the Atmosphere" technique. A pressure gauge and relief valve shall be installed at the top of the casing when this system is used.

52.000-300-000. ***Two Pipe System.*** The development process shall be carried out by the utilization of an air introducing pipe and an air and water eductor line. The compressors, air lines, hoses, fittings, etc., shall be of adequate size to pump the well by the air lift method at 1½ to 2 times the design capacity of the well. The CONTRACTOR shall initially develop the well as outlined in Article 52.000-200-000, the "Single Pipe System Closed to the Atmosphere," with the air line introducing air into the eductor line at a point above the bottom of the eductor line. When the well yields clear sand-free water, the air line shall be lowered to a point below the bottom of the eductor line and air introduced until the water between the eductor pipe and the casing is raised to the surface. At this time the air line shall be raised back up into the eductor line causing the water to be pumped from the well through the eductor line. The procedure of alternating the relative positions of the air and eductor line shall be repeated until the water yielded by the well remains clear when the well is surged and backwashed by this technique.

DEVELOPMENT AIDS

52.000-010-000. ***Washing with Water.*** Clean, clear water shall be circulated to remove sediment from the well. A pump of sufficient size shall be utilized for the washing process which will agitate the formation for the purpose of preventing bridging of the sand particles and removing a large portion of the finer material. The use of any chemicals, if pay is to be received, must be approved by the OWNER or PROJECT REPRESENTATIVE.

52.000-020-000. ***Washing with Chemicals.*** Where applicable and required, mud dispersing agents (such as glassy phosphate), acids for washing limestone, and other chemicals applicable to standard procedures may be used in accordance with the approval or direction of the OWNER or his representative.

SAND CONTENT TESTING

52.000-001-000. ***Sand Content Testing.*** The sand content shall be determined by averaging the results of 5 samples collected at the following times during the final pumping test: (1) 15 minutes after start of the test; (2) after ¼th of the total planned test time has elapsed; (3) after ½ of the time has elapsed; (4) after ¾ths of the time has elapsed; and (5) near the end of the pumping test.

The minimum volume of water sample collected for testing for sand content shall be the test rate of flow in gpm multiplied by 0.05, with the exception that the maximum volume required for wells test pumped at more than 1000 gpm shall be 50 gallons (U.S.) and the minimum required for wells tested at less than 20 gpm shall be 5 gallons (U.S.).

Sand content shall be determined in the following manner. When the circular orifice meter is used to measure flow rate, the sample shall be withdrawn from a manometer connection. When other devices are used for measuring flow rate on wells of a lower production rate, a sample may be collected directly from the full and open discharge. The sample shall be allowed to settle not less than 10 minutes before the liquid is decanted. The sand content in ppm is read directly via such devices as that illustrated in the Preamble to this Article.

SAND CONTENT LIMITS

†52.000-000-100. Well development shall continue until ______ ppm sand content is achieved as measured according to Article 52.000-001-000 or until ordered stopped by the OWNER or his representative.

52.000-000-200. Wells supplying water for flood-type irrigation and where the nature of the water-bearing formations and the overlying strata are such that pumping the following amount of sand will not seriously shorten the useful life of the well: Limit—15 ppm.

52.000-000-300. Wells supplying water to sprinkler irrigation systems, industrial evaporative cooling systems, and other uses where a moderate amount of sand is not especially harmful: Limit—10 ppm.

52.000-000-400. Wells supplying water to homes, institutions, municipalities, and industries other than those mentioned in Articles 52.000-000-300 or 52.000-000-500: Limit—5 ppm.

52.000-000-500. Wells supplying water to be used directly in contact with or in the processing of, food and beverages: Limit—1 ppm.

RECORD OF MEASUREMENT

52.000-000-010. ***Recording Measurements.*** A record shall be made showing time, type of operation, specific capacity during pumping, pumping rate and the sand content measured and recorded. These records shall be submitted to the OWNER or his representative.

METHOD OF PAYMENT FOR WELL DEVELOPMENT

52.000-000-001. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (52) shall be paid for as a lump sum.

Option B (Time and Materials): All the work performed under this Article (52) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus per cent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (52) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus per cent of add-on bid:

a. Well Development ....Unit Price/Hour
b. Chemicals ....Unit Price/Bag

Article 53
Well Testing For Performance

PREAMBLE

Data obtained from pumping tests, which are in fact the reasons for testing, will provide information necessary to determine the capacity of the well, aquifer characteristics, well efficiency, pumping rates, pump installation depth settings and other factors which will be of value in the long term operation and maintenance of the well. The type of tests chosen at any time are dependent upon the intended use of the well and the costs. The information obtained can provide data for aquifer analysis as well as for well construction. In selecting the type of pumping tests to be used, the "pit-falls" as well as the benefits must be known and considered. Performance test requirements should be consistent with the dimensions of the well, the capacity of the well, and the rate at which it will be pumped when placed in service. Care must be taken to avoid excessive pumping rates with respect to both the productivity of the aquifer and the requirements of the user. Lastly, but probably most important, the tester should not have preconceived opinions on what the well/aquifer system will yield.

Design of the well should be based on facts derived from careful analysis of data from properly conducted tests.

Depending on the size and intended use of the well, initial testing for performance may range from a simple bailing test of relatively short duration to a completely instrumented test involving "step," "continuous" and "variable rate" testing lasting 72 hours or longer. For small installations the CONTRACTOR usually has sole responsibility for the testing, while for larger wells his responsibility may be limited to the continuous uniform operation of the equipment, changing the rates of discharge, and measuring discharge and drawdown as directed by the OWNER or his representative. Regardless of the responsibility involved, certain basic practices should be followed in making any well test.

After development is completed and the test is scheduled by the OWNER, a test pump capable of pumping approximately 150 percent of the desired yield is installed in the well. The CONTRACTOR then makes the test at the specified rate and duration. Test measurements are to be taken in the manner specified and at the required time intervals. The test should not be started until the static level has recovered after development has been completed. Discharge should be accurately measured and maintained within 5 percent of the testing rate during pumping tests. For bailing tests the procedure should be as uniform as possible.

Extreme care must be taken to measure water levels before, during and after performance testing. For proper interpretation of measurements made during pumping or recovery, a static or non-pumping water level trend must be established. This is done by making periodic measurements of the static water level in the well for a period of time at least equal to the duration of the proposed test and prior to its start. Water levels should be measured with a steel tape, by flagging the bailer line, by reading pressure on an air line, or with an electric sounder (preferably used through a ½-inch or larger conduit). Recovery readings of water level in the well are started immediately upon shutdown of the test-pump and taken at specified time intervals thereafter.

The amount and rate of drawdown and recovery of the water level with time, are the most critical items of data needed to evaluate the initial efficiency of the well and the hydraulic characteristics of the aquifer.

With small-capacity wells which will operate intermittently or irregularly, testing should continue until an apparent stability of bailing or pumping level is achieved. Ideally, with large-capacity wells, pumping should be continued at a uniform rate of discharge until the cone of influence reflects any boundary condition which could affect future performance of the well. This probably will not exceed 24 hours for an artesian well, and 72 hours for a water table well. All test pumping data, including recovery data should be submitted to the OWNER or his representative upon completion of the test.

Comprehensive aquifer tests, require a minimum of one or two observation wells, depending on the purpose of the test results or the well. In typical situations observation wells may be from 100 to 300 feet from the production well and about the same depth. Observation wells may be smaller in diameter, however. For testing relatively thick artesian aquifers, observation well distance of 300 to 700 feet from the pumped well are not uncommon.

Types of Pumping Test Performed

53.100-000-000. ***Bailing Test Method.*** The CONTRACTOR shall measure the static level of the water in the well. Next he shall select a bailer of known volume only slightly smaller than the casing and calculate or measure and record its volume. He shall then bail the well until he can no longer lower the water level; he shall then lower the bailer until it hits the water (a fast falling bailer makes an audible sound when it hits the surface), and mark the bailing line with paint at a point level with the top of the casing when the bottom of the bailer is just touching the water. A second mark is then made one bailer length above the first. Rhythmically bailing, he shall lower the line precisely to the second mark on the cable each time, noting the elapsed time per round trip. He shall make sure the bailer is full each time it emerges from the well. If the bailer is not full, it is not to be lowered deeper; however, the rate of bailing is to be slowed until the bailer comes out full each time. The bailing rate, in gallons per minute, equals the volume (gal) of the bailer divided by the time (min) per round trip.

On occasion there may be less depth of water in the well than the length of the bailer. In such instances it is manifestly impossible to bring the bailer out full on each trip or to lower it below a certain point. Instead, the CONTRACTOR shall measure the amount of water in the bailer and relate it to a timed interval of 1 minute for each time the bailer leaves the bottom of the well.

53.200-000-000. ***Air Blow Test Method.*** The well shall be tested for 30 minutes by introducing air in sufficient quantity to blow the water out of the well. The discharge of the air shall be at the bottom of the hole. A deflector shall be placed at the top of the well to deflect the water downward outside the well. A dike shall be constructed around the well to contain the deflected water, and a discharge pipe shall be placed near the top of this dike and the water allowed to discharge through it. A container of known volume shall be used to collect water from this discharge for a measured period of time and the rate (gpm) shall be calculated from this information and recorded.

53.300-000-000. ***Air Lift Test Method.*** The well shall be tested by the air-lift method. The velocity in the eductor pipe shall be from 1,000 to 2,000 feet per minute. The air should be as finely divided as possible as it is introduced into the water. A series of upward-pointing jets shall be placed in the air line.

The submergence of the pipe shall be 60 percent. Submergence is the length of the eductor pipe from its open lower end to the pumping level as related to the total length of the eductor pipe.

Drawdown in a well in which an air-lift pump is working shall be measured between the casing and the educator pipe by any of the conventional methods. A deflector shall be placed at the top of the well to deflect the water downward outside the well. A dike shall be constructed around the well to retain the water. A discharge pipe shall be placed near the top of this dike and the water allowed to discharge through it. A container of known quantity shall be used to collect water from this discharge for a measured period of time and the rate (gpm) shall be calculated from this information and recorded.

§55.400-000-000. ***Variable Rate Method.*** The CONTRACTOR shall furnish, install and remove the necessary measuring instruments and pumping equipment capable of pumping to the required place of discharge a minimum of ______ gpm (lps) with a pumping level of ______ feet (meters), and with satisfactory throttling devices, so that the discharge may be reduced to ______ gpm (lps). The pumping unit shall be complete with prime mover of ample power, controls and appurtenances, and shall be capable of being operated without interruption for a period of ______ hours. The pump shall be set at the depth of the lowest producing zone and pumped at the design rate until the pump breaks suction. If the pump does not break suction for a period of 24 hours, the test shall be completed as a continuous rate test. If the pump breaks suction, the rate shall be slowly decreased until the pumping level stabilizes approximately 2 feet (0.6 m) above the pumping intake for a period of not less than 5 minutes. The pumping rate shall then be decreased 5 percent and the well pumped at this rate until the pumping level stabilizes for 1 hour. The discharge rate and drawdown thus established shall then be maintained for at least 4 hours. This pumping rate shall be considered the available production rate of the well, and the observed pumping level during the test shall be considered the production pump's pumping level.

§55.500-000-000. ***Constant Rate Method.*** The CONTRACTOR shall furnish, install and remove the necessary measuring instruments and pumping equipment capable of pumping to the required point of discharge a minimum of ______ gpm (______ lps), with a pumping level of ______ feet (______ m), and with satisfactory throttling devices, so that the discharge may be reduced to ______ gpm (______ lps). The pumping unit shall be complete with an ample power source, controls and appurtenances and shall be capable of being operated without interruption for a period of ______ hours.

The well shall be pumped at a discharge rate of ______ gpm (______ lps) for a minimum of ______ hours. The test pump shall have its intake at least 5 feet (1.5 m) below the estimated lowest pumping level, and shall have sufficient power and capacity to achieve the designated discharge rate. Discharge shall be measured with an accurate totalizing meter and stopwatch, a circular orifice meter, or a Venturi meter, any of which are subject to approval by the OWNER or his representative. Discharge shall be maintained within plus or minus 5 percent of the designated rate by means of a gate valve or throttling device. Discharge shall be checked and adjusted, if necessary, every 10 minutes during the first hour of pumping and at 30-minute intervals thereafter. The discharge and time of measurement shall be recorded each time it is checked and a note made of any adjustments. The static or non-pumping water level trend shall be established prior to the start of the test. Drawdown shall be measured according to the following schedule: 0 to 10 minutes—every minute; 10 to 45 minutes—every 5 minutes; 45 to 90 minutes—every 15 minutes; 90 to 180 minutes—each half hour; 180 minutes to the end of the test—each hour. Should the measurements not be made exactly at the times specified, the actual time of each measurement shall be recorded. On completion of pumping, recovery measurements shall be made according to the above drawdown schedule.

§55.600-000-000. ***Step-Continuous Composite Method.*** The CONTRACTOR shall furnish, install and remove the necessary measuring instruments and pumping equipment capable of pumping to the required point of discharge a minimum of ____ gpm (____ lps), with the pumping level of ____ feet (____ m), and with satisfactory throttling devices, so that the discharge may be reduced to ____ gpm (____ lps). The pumping unit shall be complete with an ample power source, controls and appurtenances and shall be capable of being operated without interruption for a period of ____ hours.

Prior to starting the pump, water level measurements shall be made at least hourly, for a minimum of eight hours, in the production well and all observation wells, and these measurements shall be recorded on the same note sheets to be used during the pumping test. The well shall be "step" tested at rates of approximately ½, ¾, 1 and 1½ times the design capacity of ____ gpm (____ lps). The complete test is estimated to require approximately ____ hours. The CONTRACTOR shall operate the pump and change the discharge as directed by the OWNER. Discharge of the pump shall be controlled by a gate valve, if electric driven, and both gate valve and engine throttle if engine driven. The discharge shall be controlled and maintained at approximately the desired discharge for each step with an accuracy of plus or minus 5 percent. Pump discharge shall be measured with a totalizing meter and stopwatch, circular orifice meter, or Venturi meter as approved by the OWNER. A ½ inch (1.27 cm) nominal diameter or larger pipe shall be installed from a point 2 feet (0.6 m) above the pump intake to the well head. The top of the pipe shall be readily accessible to insert, remove, and read the depth to water measurements on a 2-wire electric sonde, which shall be used to measure the static water level and drawdown in the well. A clearly marked convenient reference point shall be set at the top of the pipe. The sonde shall be furnished by the CONTRACTOR.

After recovery from the step test is complete, a constant rate test shall be conducted by pumping the well at the design rate or at maximum yield for a period of not less than 24 hours and until the pumping level remains constant for at least 4 hours, or until the OWNER or his representative terminates the test.

Measurements of pumping rate and water level shall be made every 1 minute for the first 10 minutes of the test, every 2 minutes for the next 10 minutes, every 5 minutes for the next 40 minutes, every 15 minutes for the next hour, every 30 minutes for the next 3 hours, and hourly for the remainder of the pumping period. Recovery water-level measurements shall be made with the same frequency until sufficient data have been collected to extrapolate the full recovery of the well or until the OWNER requires no further data.

Aborted Tests

53.010-000-060. ***Aborted Test.*** Whenever continuous pumping at a uniform rate has been specified, failure of pump operation for a period greater than one per cent of the elapsed pumping time shall require suspension of the test until the water level in the pumped well has recovered to its original level. For the purposes of this Article, recovery shall be considered "complete" after the well has been allowed to rest for a period at least equal to the elapsed pumping time of the aborted test—except that if any three successive water level measurements spaced at least 20 minutes apart show no further rise in the water level in the pumped well, the test may be resumed immediately. The (Engineer, Owner's Representative) shall be the sole judge as to whether this latter condition exists.

Location of Discharge

†53.071-000-000. ***Discharge Water.*** Discharged water shall be conducted from the pump to the nearest surface-water body, storm sewer, or ditch, as approved by the OWNER or his representative or at least a distance of ______ feet (______m) through approved piping or lined ditches to prevent recirculation of discharged water into the aquifer being tested. It is imperative to insure that no damage by flooding or erosion is caused to the chosen drainage structure or disposal site.

Record of Pumping Tests

53.080-100-000. ***Records.*** The CONTRACTOR shall keep accurate records of the pumping test and furnish copies of all records to the OWNER or his representative upon completion of the test. The records shall also be available to the OWNER or his representative for inspection at any time during the test. For each well used in the test, the records shall include physical data describing the construction features such as, but not limited to: well depth and diameter, complete screen description, length, and setting; a description of the measuring point and its measured height above land surface and/or mean sea level; the methods used in measuring water levels and pumping rates. An accurate description or sketch map of the well locations with identifying names or numbers and distances between wells or from bodies of water shall be provided on each set of records. Records of measurements shall include the date of the test, the clock time and elapsed pumping time of each measurement, the depth to water below the measuring point, the pumping rate at the time of measurement, and any pertinent comments on conditions that may affect the measurements. Frequency of water-level measurements before, during, and after pumping shall be as specified by the OWNER or his representative.

MEASUREMENT OF WATER LEVELS

53.000-010-000. ***Bailer Line Method.*** Bailing line shall be marked and measured from the bottom of the bailer to a point which is even with the top of the casing when the bailer encounters water. On the last run of the bailer on a bailer test, this measurement will be recorded as the "bailed down" level.

53.000-020-000. ***Contractor's Choice.*** The method of taking water level measurements shall be at the discretion of the CONTRACTOR; however, accuracy to within plus or minus .05 feet (1.5 cm) must be attained. Accuracy may be required under special conditions to within plus or minus .01 feet (0.3 cm).

53.000-030-000. ***Air Line Method.*** A ¼ inch (.64 cm) tube free of air leaks shall be installed in the well with the test pump, terminating 5 feet (1.5 m) above the pump intake. The tube shall have an accurate altitude gage and air valve attached to it at the surface. The vertical distance from the bottom of the air line to the center of the gage shall be recorded. The line shall then be charged with air under pressure of at least 1 pound per square inch (0.1 Kg/cm^2) for each 2 feet (0.6 m) of air line and until the gage will read no higher, and the water level in the well computed by subtracting the altitude in feet registered on the gage from the length of the air line. This method is not recommended for small drawdowns due to its lack of precision.

53.000-040-000. ***Steel Tape Method.*** Water levels less than 300 feet (90 m) deep may be measured by chalking a weighted steel tape, lowering it a known distance into the well and determining the depth by subtraction of the submerged part of the tape as indicated by the wetted chalk mark. If the steel tape is to be lowered through a metal or plastic tube, the tube must be of _______ inches (_______ cm) in diameter and its bottom must terminate approximately 2 feet (0.6 m) above the pump intake.

53.000-050-000. *Electric Sounder Method.* A ½ inch (1.27 cm) or larger diameter pipe shall be installed in the well from the surface to 2 feet (0.6 m) above the pump intake. The upper end of the pipe shall be so arranged that an electric sounder and line may be easily inserted, lowered, and read. Static water level, drawdown, and recovery measurements shall be made through this pipe, which shall have a clearly marked and readily accessible reference point at the top.

COLLECTION OF WATER SAMPLES

53.000-001-000. *Water Samples and Analysis.* See Article 55 of these standards, "Water Samples and Analysis".

METHOD OF PAYMENT FOR TESTING FOR PERFORMANCE

53.000-001-000. *Method of Payment.*

Option A (Lump Sum): All of the work performed under this Article (53) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (53) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus per cent of add-in bid.

Option C (Unit Price): All of the following work performed under this Article (53) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid.

a. Installation and Removal of Testing Equipment ...... Lump Sum
b. Recovery Stand-by Time .... Unit Price/Hour
c. Discharge Pipe .... Unit Price/Foot

Article 54
Well Disinfection

PREAMBLE

General aspects of well disinfection for which standards should provide clarification are:

A. Inspection for and removal of foreign matter is a necessary prerequisite to well disinfection.
B. The specific time in the overall well construction schedule at which the disinfection is required.
C. The amount of disinfecting agent to be used and the contact time required.
D. The establishment of equipment and work procedures required in carrying out the disinfection.

Well cleaning is a necessary part of well construction. Contaminants in the form of grease, oil, soil and other foreign substances can harbor and protect bacteria from subsequent disinfection. Generally mechanical extraction, swabbing and pumping have proved effective for most cleaning requirements. Cleaning and disinfecting chemicals should only be employed where responsible and competent authority has approved their use, the amount to be used and the method to be employed.

Suggestion for periodic disinfection during construction, disinfection of the well drilling equipment, and for adding granulated calcium hypochlorite during artificial filter installation appear in the literature dealing with well construction. The effectiveness of periodic disinfection is questionable considering the conditions under which it likely would be carried out. Experience with the disinfection of pipelines shows that clean conditions are necessary for chlorination to be effective. Clean conditions necessary for effective well disinfection may be inherent in the techniques used for the construction of the well, as when a surge plunger and pumping are used for development.

Well drilling equipment and tools should be kept clean and a conscientious effort made to prevent the transporting of foreign material from one well site to another. Water used for the drilling fluid should be clean and free of organic material and/or minerals which would impair the qualities of the drilling fluid. This does not preclude the use of approved commercial organic drilling fluid additives.

Normal water well disinfection practice is to utilize a chlorine solution prepared with either calcium hypochlorite—powdered or tablet form—or sodium hypochlorite in liquid form. The effectiveness of a chlorine solution is generally misconstrued to be the theoretical amount of free chlorine in the solution. Actually, the effectiveness of the solution is primarily related to the amount of hypochlorous acid (HOCl) present and not to the total free chlorine, commonly referred to in regulations dealing with well chlorination. Because the formation of HOCl is retarded at higher pH values, and standard chlorine compounds increase pH, a 100 ppm chlorine solution—prepared with neutral (pH 7) water—may be a less effective germicide than a 50 ppm solution prepared with water of lower pH. Effectiveness is also related to the amount of contact time. With a contact time of 8 hours, or more, chlorine solutions of 50, 100 or 200 ppm apparently provide adequate effectiveness against pathogenic organisms.

It should be noted here that appropriate compounds of iodine, bromine, ozone or other disinfectants may be used in place of chlorine, with the approval of state and local regulatory agencies.[6]

The following paragraphs represent special conditions rather than normal disinfection practice:

A. Where the ground water has a low pH value caution should be exercised with the use of chlorine as a disinfecting agent due to the highly corrosive nature of a chlorine solution with a low pH value.

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[6] EPA considers chlorine and chlorine-releasing compounds to be the only practical disinfectants for well disinfection.

B. As noted previously, continuous or periodic disinfection during the construction of a well may be desirable. In such instances care is required to insure that disinfection not interfere with the work of construction.

C. Interim chlorination with a solution of 5 to 10 ppm of free chlorine is advisable when several days will elapse between well completion and the carrying out of normal disinfection required by regulatory agencies. While not normally acceptable for final disinfection by most state regulatory agencies a chlorine dose of 5 to 10 ppm should provide adequate protection where prolonged contact time—days rather than hours—is assured. Where domestic wells are complete weeks before permanent pumping equipment is installed an interim disinfection with a 5 to 10 ppm concentration should be carried out with the solution remaining in the well for the entire interval between well completion and the time the permanent pump is installed.

Scheduling of disinfection should not pose a problem regardless of the type of well involved. It should not be delayed pending the installation of a permanent pump but should immediately follow completion of the well. For public water supply wells or industrial wells a pumping test is usually required. In such instances disinfection should be done upon installation of the test pumping equipment. The chlorine is expelled from the well during the test pumping.

It is of major importance in well disinfection to insure adequate distribution of the disinfecting agent in the well and also to that part of the well above the static water level. Where disinfection with a dry chlorine compound is necessary or permitted—without first preparing a liquid solution—appropriate means must be provided to achieve a relatively even application of the compound to the bottom of the well screen and throughout the well. Pellets or powdered chlorine compound must be used with a mechanical carrier. Usually a solution is prepared prior to placement of the disinfectant into the well.

Unless the solution is evenly distributed the disinfectant may move laterally rather than to the bottom of the well. An appropriate tremie device—hose or pipe—should be employed to insure proper distribution of the disinfectant. Agitation through use of a bailer, surge block, or by intermittent stopping and starting of a test pump, is recommended to force some of the solution into the water bearing formation around the well. However, agitation is not an alternative to adequate distribution of the concentrated chlorine solution.

If a test pump is available during disinfection it provides a convenient means for application of the disinfecting solution to the dry part of the well. The discharge piping of either a test pump or permanent pump should incorporate a tap and hose connection on the pump side of a valve in the discharge piping, to facilitate application of the chlorine solution in the well to the dry part of the well through a hose. Intermittent pump operation for surging will not interfere with hose application of the solution to dry parts of the well, and in keeping such parts wet for an adequate period of time. When a pumped supply of dilute chlorine solution is not available for this purpose, a separate tank and gravity system will be needed.

Although partial disinfection of the well system may be done during testing, a final disinfection must be the final act of well construction, eliminating any chance of contamination.

SCHEDULING DISINFECTION

54.100–000–000. The CONTRACTOR shall provide for disinfection as soon as construction of the well and cleaning procedures have been completed. The **CONTRACTOR** shall carry out adequate cleaning procedures immediately preceding disinfection where evidence indicates that normal well construction and development work have not adequately cleaned the well. All oil, grease, soil, and other materials, which could harbor and protect bacteria from disinfectants, shall be removed from the well. Unless prior approval is obtained for employing chemicals or unusual cleaning methods, the cleaning operation is to be carried out by pumping and swabbing only. Where test pumping equipment is to be utilized, such equipment shall be installed prior to or during disinfection and be thoroughly hosed, scrubbed or otherwise cleaned of foreign material.

DISINFECTANTS

54.010–000–000. Chlorine or other compounds approved by state or local regulatory agencies shall be used as disinfectants. The disinfectant shall be delivered to the site of the work in original closed containers bearing the original label indicating the percentage of available chlorine. The disinfectant shall be recently purchased. Chlorine compounds in dry form shall not be stored for more than one year and storage of liquid compounds shall not exceed 60 days. During storage, disinfectants shall not be exposed to the atmosphere or to direct sunlight. Unless superseded by governmental regulation, the quantity of chlorine compounds used for disinfection shall be sufficient to produce a minimum of 50 ppm (parts per million)[8] available chlorine in solution when mixed with the total volume of water in the well. A 50 ppm solution should result from utilizing quantities of chlorine compounds, proportion to the depth of water, as listed in Table 12.

INTERIM DISINFECTION

54.001–000–000. Should a delay of three days or more be anticipated between the completion of the well and the regularly scheduled well disin-

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[8] EPA recommends a minimum concentration of 100 ppm available chlorine for effective well disinfection.

TABLE 12.—*Chlorine Compound Required To Dose 100 Feet of Water-Filled Well at 50 ppm***

1	2	3	4	5
		Chlorine Compounds		
Casing diameter (inches)	Volume (100 ft) (gal)	70% HTH Perchloron, etc. (dry weight)*	25% Chloride of Lime (dry weight)*	5.25% Purex Clorox, etc. (liquid measure)
2	16.3	¼ oz	½ oz	2 oz
4	65.3	1 oz	2 oz	9 oz
6	146.9	2 oz	4 oz	20 oz
8	261.1	3 oz	7 oz	2½ pts
10	408.0	4 oz	11 oz	3½ pts
12	587.5	6 oz	1 lb	5 pts
16	1,044.5	10 oz	1¾ lbs	1 gal
20	1,632.0	1 lb	3 lbs	1⅝ gals
24	2,350.1	1½ lbs	4 lbs	2⅜ gals

NOTE: Liquid sodium hypochlorite in a 12 percent solution is often sold for water and wastewater treatment plant use, as a commercial bleach, or for use with swimming pools. Utilizing a solution of this nature would call for a liquid measure equal to one-half the volumes presented in Column 5.

* Where a dry chemical is used, it should be mixed with water to form a chlorine solution prior to placing it into the well.

** EPA recommends a minimum concentration of 100 ppm available chlorine. To attain this concentration, double the amounts listed in Table 12.

fection an interim disinfection shall be provided by the **CONTRACTOR**. The **CONTRACTOR** shall install an approved disinfecting agent in an amount equal to 10 percent of the amount required for final disinfection. For this purpose the disinfecting agent shall be furnished or prepared in liquid form and placed in the well through a hose or tremie of sufficient length to extend to the bottom of the well. The disinfecting agent shall be applied through the hose, which is to be raised and lowered, to achieve uniform distribution of the solution throughout the well.

DAILY OPERATION: DISINFECTION

54.000–100–000. Daily chlorination of the well shall be carried out by the **CONTRACTOR** during drilling operations. The **CONTRACTOR** shall discuss with the **OWNER** the amount of disinfecting agent to be used and its method of use in advance of initiating the work. Chlorine compound dosages and method of utilization shall be satisfactory to the **OWNER** in its entirety.

DISINFECTION PROCEDURE

54.000–010–000. Unless otherwise modified—due to problems involved with the specific well or conflict with local, state or federal governmental regulatory agency requirements—disinfection procedure shall include, but not be limited to the following:

Provide reliable means for insuring that the disinfecting agent is uniformly applied throughout the entire water depth of the well without relying on subsequent mechanical or surging action for dispersing the disinfectant; the dispersion of the disinfectant shall be assisted by pouring into the well a volume of water equal to the volume of the screen, after the disinfectant has been emplaced. This will cause the disinfectant to flow out of the well into the area adjacent to the screen.

All accessible portions of the well above the water level shall be maintained in a damp condition with water containing the required concentration of disinfecting agent for a period of not less than 20 minutes. The disinfecting agent shall be left in the well for a period of at least 12 hours. After a 12 hour, or longer, contact period the well is to be pumped to clear it of the disinfecting agent. The disposal point for the purged water shall be as selected so as to minimize potential damage to aquatic life or vegetation.

DISINFECTION OF WATER TABLE WELLS

54.000-001-000. ***Dry Chlorine Compounds.*** A doubly capped, perforated pipe container filled with the appropriate amount of a granular chlorine compound for the well shall be moved up and down the entire well bore until the material has dissolved.

†54.000-002-000. ***Stock Solution (I).*** A stock solution sufficient to produce ________ ppm of available chlorine shall be added to the well at different intervals from top to bottom and then agitated to distribute it evenly throughout the well.

†54.000-003-000. ***Stock Solution (II).*** A stock chlorine solution of 15,000 ppm shall be added to a continuous flow of water into the well to produce a ________ ppm concentration of available chlorine throughout the well.

54.000-004-000. ***Prepared Solution.*** The chlorine solution of the appropriate concentration to disinfect the well shall be prepared on the surface in containers having an aggregate volume equal to at least twice the volume of water in the well and then rapidly discharged into the well so as to thoroughly flush that portion of the casing which is above the water level.

DISFECTION OF FLOWING ARTESIAN WELLS

54.000-000-100. ***Dry Chlorine Compounds.*** A doubly capped, perforated pipe container filled with a granular chlorine compound shall be placed at a point on or below the top of the producing horizon. This process shall be repeated as often as necessary to achieve and maintain the standard 50 ppm concentration for a period of not less than one hour.

54.000-000-200. ***Controlled Flow Disinfection.*** Flow shall be controlled by either capping or by a suitable standpipe. In the event the well is capped a stock chlorine solution shall be injected, under pressure, by means of a droppipe to the bottom of the well. The cap shall be equipped with a suitable one-inch valve. After the injection is complete air shall be injected for agitation while simultaneously opening the valve in the cap permitting the chlorine solution to be dispersed to the surface. The valve shall then be closed and the flow stopped. The chlorine concentration shall be maintained at 50 ppm. for six hours.

In the event flow can be controlled by a suitable standpipe the chlorine treatment can be conducted as though the well was non flowing.

54.000-000-300. ***Stock Solution.*** A stock chlorine solution shall be applied for a period of not less than one hour at a point at or below the top of the producing zone. The rate of application will be such that the standard 50 ppm concentration is achieved and maintained during the application period.

METHOD OF PAYMENT FOR WELL DISINFECTION

54.000-000-410. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (54) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (54) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (54) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

a. Well disinfection	Unit Price/Hour
b. Chemicals	Unit Price

Article 55
Water Samples and Analyses

PREAMBLE

To determine the quality of ground water which will be available from each well and its suitability for intended uses, the water in all wells should be sampled during or immediately following construction and development, and appropriate field and laboratory analyses based on the intended uses should be made.

Chemical Quality

Knowledge of the quality of water encountered as the well is being constructed is highly desirable, and in some instances imperative because such knowledge can affect decisions regarding continued construction, selection of materials, and modifications in construction or in the planned operation of the completed well. Common examples of quality related problems are: water zones to be excluded by casing or grouting; choice of casing material; selective casing perforation; selection of screen materials; screen setting; and the installation and operation of water conditioning equipment.

While the quality of the water pumped is of prime interest to the OWNER, the importance of establishing the quality of water available for each aquifer penetrated is often overlooked. Water quality determinations should be made as soon as possible after penetration of each new source.

In extensively developed areas, determination of quality may be simply a matter of verifying what already has been learned of water quality from nearby wells.

The usefulness of any water quality analysis depends on the collection of a representative sample. The cost of laboratory analysis can be wasted if sampling is done carelessly or by those without training or experience.

Sample Collection For Chemical Analyses

The method used to collect samples for chemical analyses depends in part on the drilling method, the intended purpose and yield of the well, and the information desired. The simplest procedure consists of lowering a container into the well, allowing it to fill, and raising it to the surface. The bailer is such a device. More sophisticated devices for collecting samples at preselected depths have been developed. The so-called "thief" sampler and the ball type sampler are the most used of these devices. By collecting samples at selected depths, it is possible to obtain a quality "profile" of the well or borehole. Sampling with a bailer is common to the cable tool method of drilling, particularly where well yields are small.

For wells of larger yield, pumped samples may be required. In some instances the interval to be sampled is segregated by sealing-off the rest of the well, installing a screen in the interval and pumping, beginning at a low rate and increasing the rate until mud and other materials which will affect the chemical analysis are removed. The process could take 24 hours or more.

Usually, samples are collected from the discharge during test pumping or after the production pump is installed.

Samples should be collected after the well has been pumped (or bailed) long enough to remove standing water, mud and other foreign material, including development and disinfectant chemicals, so as to insure that ground water has entered the well and the sample is representative of the water in the aquifer(s).

Quite often determination of quality must be made during the initial stages of construction to help decide whether to proceed with the work. Determinations may also be made to find out if water of undesirable quality has been encountered so as to exclude it, or to adjust or finalize the design of the well. This determination can best be made during the drilling and sampling phases of the construction.

Bacteriological Quality

Testing for bacteriological quality is the final step in well completion. The sample is collected from the pump discharge after the well has been disinfected and the chlorine removed by pumping.

It occasionally happens following "disinfection" of a well that became heavily contaminated during construction, that a positive (bad) result is reported by the laboratory. This calls for disinfection and testing to be repeated. Failure to obtain negative (good) results after a second disinfection is reason to question the disinfected materials and procedures used, the sanitary protection of the well, or possibly the quality of the water in the aquifer. If the well cannot be cleared of contamination, another source of water should be developed or steps taken to provide continuous chlorination of the water before use.

The delays, extra work and cost associated with having to repeat well disinfection procedures are compelling arguments for using adequate quantities of disinfectant and doing a thorough job the first time.

Sample Collection for Bacteriological Analysis

Collection of samples for bacteriological examination must be done carefully to avoid contamination of the water, the bottle, or the cap. Preferably, sample collecting should be done by specially trained persons; some agencies refuse to accept water for analysis that has not been collected by authorized persons. Technical assistance and advice can usually be obtained from local or state health departments.

Samples for bacteriological analysis are usually collected from the pump discharge after the production pump has been installed and all of the disinfectant pumped from the well. Special care must be taken to avoid contacting the inside of the bottle or the cap with the fingers, and to avoid having the water splash from the hands into the bottle.

Suitable sterilized bottles are available from the agency or laboratory making the analysis.

Field Tests

Tests for chemical and physical quality of water, performed in the field, can be very helpful in making preliminary decisions affecting construction and in detecting the presence of certain substances that would otherwise be lost in the time it takes for the sample to arrive at the laboratory. A few such substances are: carbon dioxide gas, oxygen, and hydrogen sulfide gas. Chemicals are usually added in the field to ensure the accuracy of iron and manganese determinations when the samples are brought to the laboratory for analysis.

Field tests for water quality are intended to supplement—not replace—the laboratory determinations. Most of the analysis cannot be as accurately performed in the field with portable equipment as in the laboratory.

Specific electrical conductance is one field test that provides an approximation of the mineral content of the water. Because the property of water to conduct electricity depends on the amount and kinds of mineral salts dissolved in the water, there is a direct correlation between the conductivity of the sample (indicated on the meter) and the total mineral content (calculated). This same principle is sometimes applied in a different way when an "electric log" has been run in the completed bore hole. Resistivity (the reciprocal of conductivity) values and other data from the log can be used to determine in a general way the relative mineral content of the water in the formations penetrated by the bore hole.

Accurate interpretation requires considerable experience and a knowledge of aquifer characteristics.

Field determinations for the presence of bacteria are possible using the membrane filter technique. Considerable care and skill are required, however, and the test is seldom run in the field unless there is urgent need to get results quickly. Final judgment of the bacteriological quality of the water should be based on tests made in approved laboratories.

Laboratory Tests

Laboratory tests should be performed by reputable laboratories, preferably those certified by the state.

A great variety of materials may be found in the ground either naturally or as a result of man's activities. Rather than analyze for all possible substances (which would be costly and time consuming) only those which are known to be of significance should be determined. It has become standard practice to group constituents in logical combinations, for example, to form the common minerals.

Selecting constituents for which analyses should be made involves consideration of the intended use of the water, knowledge of nearby quality conditions, familiarity with requirements of state and local regulatory agencies, understanding of commonly accepted use criteria, and the exercise of good judgment.

BACTERIOLOGICAL ANALYSES

55.100-000-000. ***Bacterial.*** A sample of the water from the well should be collected and analyzed for coliform organisms after all traces of development and disinfectant chemicals have been removed from the well. If the laboratory analysis shows the water is not safe to use, disinfection and analysis shall be repeated until negative (good) results are reported by the laboratory, or until it is determined by the health department that disinfection of the well cannot overcome the problem.

ANALYSIS FOR SPECIFIC CONSTITUENTS

†55.010-000-000. ***Specific Constituent-Analysis.*** Analysis for the following specific constituents shall be made: ______, ______, ______, ______, ______. Listed below are selections that can be used to fill in the blanks above.

Common Minerals: A laboratory analysis for common constituents, including calcium, magnesium, carbonate and bicarbonate, iron, manganese, sulfate, chloride, fluoride, and total dissolved solids shall be made of any potential potable water source to assure that applicable drinking water standards are met, or that suitable treatment of the water can be provided for.

Metals and compounds: arsenic, barium, cadmium, chromium, cyanide, lead, mercury, nitrate, selenium, zinc.

Radioactivity: gross alpha particle emitters and Radium 226.

Pesticides: chlordane, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, toxaphene, azodrin, dichlorvos, dimethoate, ethion, chlorophenoxyls, others.

ANALYSIS FOR SPECIFIC PURPOSES

†55.001–000–000. ***Domestic Water Supply.*** The chemical analysis shall include the following determinations:

1. Iron
2. Total hardness
3. Alkalinity
4. pH
5. Manganese
6. Nitrates (NO_3)
7. Specific Conductance
8. ________, ________, ________

†55.002–000–000. ***Well and Treatment Facility Design.*** In order to obtain planning data for well design, well maintenance, water treatment considerations and future needs and references, water quality data shall be obtained. The preferred procedure shall be field analysis with confirming samples sent to an approved laboratory for confirmation. Chemical analysis shall include the following:

1. Total dissolved solids
2. Total hardness
3. Total iron
4. Total manganese
5. Chloride
6. Total alkalinity
7. Nitrate
8. pH
9. Ryznar Stability Index
10. Carbon Dioxide
11. Hydrogen Sulfide Gas
12. Dissolved Oxygen
13. Fluoride
14. ________, ________, ________

†55.003–000–000. ***Irrigation Water Supply.*** The chemical analysis shall include the following determinations:

1. Boron
2. Calcium
3. Magnesium
4. Sodium
5. Potassium

6. Carbon Dioxide
7. Bicarbonate
8. Sulfate
9. Nitrate
10. Total dissolved solids
11. Sodium adsorption ratio
12. ________, ________, ________

§55.004-000-000. ***Industrial Water Supply.*** The chemical analysis shall include the following determinations:

1. Total Dissolved Solids
2. Total Hardness
3. Iron
4. Manganese
5. Alkalinity
6. pH
7. Turbidity
8. Color
9. Silica
10. Stability Index
11. Saturation Index
12. Sulfates (SO_4)
13. Nitrates (NO_3)
14. Phosphates (PO_4)
15. Carbon Dioxide CO_2
16. Hydrogen Sulfide (H_2S)
17. ________, ________, ________

55.005-000-000. ***Municipal Water Supply.*** If the well is for municipal use, analyses shall be made for the constituents listed in the currently *applicable drinking water standards.*

TYPES OF SAMPLES

55.000-100-000. ***Bacterial Sampling.*** A sample of water of at least 125 milliliters (equal to about ¼ of a pint) shall be collected for bacteriological analysis; i.e., primarily for the presence of coliform bacteria. A sterile sample bottle, preferably one provided by the laboratory that will make the determination, shall be used. It is extremely important that nothing except the water to be analyzed come in contact with the inside of the bottle or the cap; the water must not be allowed to flow over an object or the hands into the bottle being filled. The sample bottle shall not be rinsed. The water should be allowed to flow to waste for several minutes to clear the service lines before the sample is taken. The sample shall be delivered to the laboratory as soon as possible, and in no event more than 30 hours after its collection. During delivery, the sample should be kept as cool as possible (but not frozen).

§55.000–200–000. ***Bacterial Sampling Plus Chemical Sampling.*** A sample of water of at least 125 milliliters (equal to about ¼ of a pint) shall be collected for bacteriological analysis; i.e., primarily for the presence of coliform bacteria. A sterile sample bottle, preferably one provided by the laboratory that will make the determination, shall be used. It is extremely important that nothing except the water to be analyzed come in contact with the inside of the bottle or the cap; the water must not be allowed to flow over an object or the hands into the bottle being filled. The sample bottle shall not be rinsed. The water should be allowed to flow to waste for several minutes to clear the service lines before the sample is taken. The sample shall be delivered to the laboratory as soon as possible, and in no event more than 30 hours after collection. During delivery, the sample should be kept as cool as possible (but not frozen).

A ______ (½, 1, 2) gallon (1.89, 3.79, 7.58 liter) sample of water shall be collected for chemical analysis. The water sample shall be collected in a new, unused polyethylene "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

§55.000–300–000. ***Bacterial Sampling Plus Chemical Sampling Plus Radiological Sampling.*** A sample of water of at least 125 millimeters (equal to about ¼ of a pint) shall be collected for bacteriological analysis; i.e., primarily for the presence of coliform bacteria. A sterile sample bottle, preferably one provided by the laboratory that will make the determination, shall be used. It is extremely important that nothing except the water to be analyzed come in contact with the inside of the bottle or the cap; the water must not be allowed to flow over an object or the hands into the bottle being filled. The sample bottle shall not be rinsed. The water should be allowed to run for several minutes to clear the service lines before the sample is taken. The sample shall be delivered to the laboratory as soon as possible, and in no case more than 30 hours after collection. During delivery, the sample should be kept as cool as possible (but not frozen).

A ______ (½, 1, 2) gallon (1.89, 3.79, 7.58 liter) sample of water shall be collected for chemical analysis. The water sample shall be collected in a new, unused polyethylene "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

A ______ (½ or 1) gallon (1.89, 3.79 liter) sample of water shall be collected for examination for radioactivity. The sample shall be collected in a new, unused polyethylene "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

§55.000–400–000. ***Chemical Sampling Only.*** A ______ (½, 1, 2) gallon (1.89, 3.79, 7.58 liter) sample of water shall be collected for chemical analysis. The water sample shall be collected in a new, unused polyethylene "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

†55.000-500-000. ***Chemical Sampling Plus Radiological Sampling.*** A ______ (½, 1, 2) gallon (1.89, 3.79, 7.58 liter) sample of water shall be collected for chemical analysis. The sample shall be collected in a new, unused polyethylene "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

A ______ (½ or 1) gallon (1.89 or 3.79 liter) sample of water shall be collected for examination for radioactivity. The sample shall be collected in a new, unused "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

†55.000-600-000. ***Radiological Sampling Only.*** A ______ (½ or 1) gallon (1.89 or 3.79 liter) sample of water shall be collected for examination for radioactivity. The sample shall be collected in a new, unused "cubitainer," or in a glass container with teflon-lined cap. The glass container shall have been chemically cleaned by the laboratory that will make the analysis.

COLLECTION METHODS

(Chemical and Radiological Anlyses)

55.000-010-000. ***Bailed Sample Method.*** A water sample shall be obtained by bailing at the time the water bearing formation is encountered, first removing as much as possible of the water which has entered from other sources. The samples shall be taken at time periods specified by the OWNER.

†55.000-020-000. ***Discharge Sample Method.*** A water sample shall be taken of the water discharged during development or test pumping after the well has been pumped for ______ (minutes, hours, days), and after development chemicals have been removed and there is minimum visual evidence of mud or fines (such as sand, etc.) in the water.

†55.000-030-000. ***Pumped Sample: Composite.*** A water sample shall be obtained by pumping from the elevation(s) designated by the OWNER with a submersible pump, air pump, or other device. The intake shall be set at the elevation(s) prescribed and the pump operated for ______ (minutes, hours, days). The sample shall not be taken until the water being pumped is free of mud or other foreign matter.

55.000-040-000. ***Point Sample.*** A water sample shall be obtained by use of a "thief" sampler, ball sampler or other similar device designed for collecting water samples at predetermined depths. Waters foreign to the depth or depths selected for sampling, and other extraneous matter, shall be removed as completely as possible prior to sampling, by pumping or bailing.

†55.000-050-000. ***Pumped Sample: Segregated (Drill Stem Test Sample).*** A water sample shall be obtained by pumping from the formation(s) designated by the OWNER. The interval to be sampled shall be segregated from the remainder of the well by inflatable packers or other means. If necessary, the interval shall be screened so as to prevent the influx of loose material. The sample shall not be taken until the water being pumped is free of mud and other extraneous matter that might affect the chemical analysis, or until the pump has been operated ______ (minutes, hours, days).

WELL HEAD TESTS

55.000-001-000. ***Temperature and pH Tests Only.*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and drillers log. Tests shall be conducted according to procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis.

55.000-002-000. ***Temperature and pH Tests Plus Gas Tests*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and drillers log. Tests shall be conducted according to procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis. Test for the presence of gases shall be made immediately following the collection in accordance with procedures prescribed by the manufacturer of the test equipment.

55.000-003-000. ***Temperature and pH Tests Plus Specific Electrical Conductance Test.*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and in the drillers log. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis. Specific electrical conductance (conductivity) shall be determined following collection using a conductivity meter that has been recently calibrated. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment.

55.000-004-000. ***Temperature and pH Tests Plus Specific Electrical Conductance Test Plus Alkalinity and Turbidity Tests.*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and in the drillers log. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis. Specific electrical conductance (conductivity) shall be determined following collection using a conductivity meter that has been recently calibrated. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment. The alkalinity and turbidity of the water shall be determined immediately upon the collection of the sample and recorded on the sample container and in the drillers log. Tests shall be conducted in accordance with the procedures prescribed by the manufacturer of the equipment local health or water agencies, or as set forth in standard publications dealing with this method of analysis.

55.000-005-000. ***Temperature and pH Tests Plus Gas Test Plus Specific Electrical Conductance Test.*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and in the driller's log. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis. Tests for the presence of gases shall be accomplished immediately following the collection. Tests shall be accomplished in accordance with procedures prescribed by the manufacturer of the test equipment. Specific electrical conductance (conductivity) shall be determined following collection using a conductivity meter that has been recently calibrated. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment.

55.000-006-000. ***Temperature and pH Tests Plus Gas Test Plus Specific Electrical Conductance Test Plus Alkalinity and Turbidity Tests.*** The temperature and pH of the water shall be taken immediately upon collection of the water sample and recorded on the sample container and in the drillers log. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment employed, local health or water agencies, or as set forth in standard publications dealing with this method of analysis. Tests for the presence of gases shall be accomplished immediately following the collection. Tests shall be accomplished in accordance with procedures prescribed by the manufacturer of the test equipment. Specific electrical conductance (conductivity) shall be determined following collection using a conductivity meter that has been recently calibrated. Tests shall be conducted in accordance with procedures prescribed by the manufacturer of the test equipment. The alkalinity and turbidity of the water shall be determined immediately upon the collection of the sample and recorded on the sample container and in the drillers log. Tests shall be conducted in accordance with the procedures prescribed by the manufacturer of the equipment, local health or water agencies, or as set forth in standard publications dealing with this method of analysis.

Standards of Test and Samples

55.000-000-100. ***Laboratory Requirements.*** Laboratory tests shall consist of those specified by the regulations of local or state government or as described herein for the proposed use of the water. In addition, such other tests prescribed by the OWNER will be made. All laboratory tests shall be performed by a laboratory approved by the OWNER or his agent. Analytical techniques and methods shall be as prescribed in *Standard Methods for the Examination of Water and Waste Water*, a joint publication of the American Public Health Association, American Water Works Association, and Water Pollution Control Federation. All samples shall be appropriately identified as to geographic location, date, time, method of collection, point of collection, water bearing formation(s), depth and diameter of well, water level and yield, and shall include the name of the sample collector, CONTRACTOR, driller and OWNER.

METHOD OF PAYMENT
FOR WATER SAMPLES AND ANALYSES

55.000-000-010. *Method of Payment.*

Option A (Lump Sum): All of the work performed under this Article (55) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (55) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at its cost plus per cent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (55) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

a. Water Analyses .... Unit Price/Test Series

Article 56
Permanent Well and Test Hole Abandonment

PREAMBLE

Unsealed abandoned wells constitute a hazard to public health, safety, welfare, and to the preservation of the ground water resource. The sealing of such wells presents a number of problems, the character of which depends upon the construction of the well, the geological formations encountered, and the hydrologic conditions. To seal an abandoned water well properly, several things must be accomplished: (1) elimination of a physical hazard; (2) prevention of ground water contamination; (3) conservation of yield and maintenance of hydrostatic head of aquifers; and (4) prevention of the intermingling of desirable and undesirable waters.

The basic concept governing the proper sealing of abandoned wells is the restoration, as far as feasible, of the geohydrologic conditions that existed before the well was drilled and constructed, for an improperly abandoned well might serve as an uncontrolled invasion point for contaminated and polluted water. Any well that is to be permanently abandoned should be completely filled in such a manner that vertical movement of water within the well bore, including vertical movement of water within the annular space surrounding the well casing, is effectively and permanently prevented and the water is permanently confined to the specific zone in which it originally occurred. If all these objectives can be accomplished, all the rules for sealing wells heretofore presented will be fulfilled.

To seal an abandoned well properly, the character of the ground water must be considered. If the ground water occurs under unconfined or water-table conditions, the chief problem is that of sealing the well with impermeable material so as to prevent the percolation of surface water through the original well opening, or along the outside of the casing, to the water table. If the ground water occurs under confined or artesian conditions, the sealing operation must confine the water to the aquifer in which it occurs—thereby preventing loss of artesian pressure by circulation of water to the surface, to a formation containing no water, or to one containing water under a lower head than that in the aquifer which is to be sealed.

Preparation For Abandonment

Strong efforts should be made to remove all materials from a well which may hinder its proper abandonment. This is especially important where specified zones must be sealed.

If a screen has been installed in the well by telescoping, its recovery is usually possible by installing a string of fishing tubing from the top of the well to a sand hitch placed close to the bottom of the screen. Following the setting of the sand hitch, a lifting force, applied either by mechanical or hydraulic jacks, or multiple pulling lines from the casing reel of the drilling machine, will usually withdraw the screen from the well.

In recovering steel casings extending to the surface, the least expensive and least hazardous method is to apply a lifting force to the casing by the use of jacks, or with the drilling machine, or with the two in combination. Still more effective is the use of a jarring head applied at the top of the casing string and used in combination with lifting devices.

Maximum recovery is usually obtained by using a trip-type casing spear actuated by a fishing cable tool string and used in combination with lifting devices. The trip spear is usually limited in its use to recently drilled wells or to those in which the casing is known to be in sound condition. The risk of failure associated with the use of a casing spear increases with the age of the well and the depth at which it is to be used.

It is always good practice to probe the well with a swage of the same diameter as the spear prior to inserting the latter.

The order of descent into the casing for a trip spear string of tools is: (1) trip spear; (2) fishing jars; (3) sinker bar or drill stem; (4) rope socket, which is attached to the drilling line. The swage would replace the spear in the above string of tools.

Where a drive shoe is attached to the bottom of a casing string to be extracted, it is often advantageous to separate the casing from the shoe. The preferred method for cutting casing is by use of a casing cutter. Some states do not permit the use of explosives inside the casing.

Borehole Bridging

To reduce cost of unnecessary backfilling of long sections of borehole, it is often desirable to establish a temporary bridge in the borehole upon which a permanent cement-based bridge can be placed. No organic materials should be used in either the temporary or permanent bridge—except that specially manufactured devices such as cement plugging tools in which neoprene rubber or plastics are used, are acceptable and these greatly facilitate the work. Some of these devices permit establishing the permanent bridge without first having to set a temporary one.

Abandonment of Flowing Artesian Wells

The flowing artesian well with improperly sealed casing and with water escaping around the outside of the casing either to the surface or to another formation presents a special problem. A necessary first step in bringing the flow under control is to establish a permanent cement seal between the casing and the point or points from which the water is escaping.

In order to place this seal effectively, the flow must be stopped and the water level lowered in the well. This can be accomplished by several methods. Some of these are: (1) pumping the problem well, thereby producing the necessary drawdown; (2) pumping nearby wells, producing the same effect; and (3) introducing high specific gravity fluids at the bottom of the borehole and filling the hole with the fluid until all flow ceases. The method or methods used will depend in part on the shut-in pressure of the well and the depth to which the water level must be lowered.

The sealing of abandoned wells that have a large movement of water between aquifers or to the surface requires special attention. The movement of water may be sufficient to make the sealing with ordinary materials and by the usual methods impractical. In such wells, large stone aggregates (not more than 1/3 of the diameter of the hole) lead wool, steel shavings, a well packer, or cast lead plug or bridge should be used to restrict the flow thereby permitting the placement of appropriate sealing material. If preshaped or precast plugs are used, they should be several times longer than the diameter of the well to prevent tilting. The flow of artesian wells to be abandoned can best be stopped with neat cement or sand-and-cement grout piped under pressure or, in some instances, by the use of a suitable well packer or cast lead plug placed at the bottom of the confining formation immediately overlying the artesian water-bearing zone.

In wells in which the hydrostatic head producing the flow is low and in which there is no escape of water below ground, the movement of water can be arrested by extending the well casing to an elevation above the artesian pressure surface. This permits the placement of sealants and fill materials, after which the casing may be cut off at or below ground level.

Abandonment of Other Borings and Holes

Mineral exploration holes, solution or "in situ" mining wells, dewatering wells, temporary service wells, construction water wells, process wells, and/or other structures that affect the withdrawal from or quality of water in the ground water reservoir, regardless of location or intended life of the structure or hole, should be abandoned as described herein for water supply wells.

Functions of Seals

Three basic types of seals—distinguished by their functions—may be used in a properly abandoned well. They are:

A. Permanent Bridge-Seal: The deepest cement seal to be placed in the well, this seal serves two purposes: it forms a permanent bridge below which considerable unfilled hole may remain and upon which fill material may be safely deposited; and it seals upper aquifers from any aquifer(s) which may exist below the point of sealing. (See Figure 4)

B. Intermediate Seal: This seal is placed between water-bearing formations which have, or are believed to have, different static heads. Its function is to prevent the interaquifer transfer of water. (See Figure 5)

C. Seal at Uppermost Aquifer: This seal is placed immediately above the uppermost aquifer penetrated by the bore hole. Its function is to seal out water from the surface and from shallower formations. In flowing artesian wells, it is designed to prevent the escape of water to the surface, or to shallower formations. (See Figure 6)

Each abandonment effort should be considered an individual problem, and methods and materials should be selected only after detailed study of both construction and geohydrology. Whenever there is doubt about either the construction or the geohydrology involved, the choices of materials and procedures should be those affording the greatest probability for successful sealing.

AQUIFER SEALING CRITERIA

56.100-000-000. ***Aquifer Sealing Criteria.*** Aquifers shall be filled with disinfected, dimensionally stable materials, compacted mechanically if necessary to avoid later settlement. (Cement, cement-and-sand, and concrete do not require disinfection.)

Disinfection of aquifer fill materials shall be accomplished by using chlorine compounds such as sodium hypochlorite or calcium hypochlorite. Aquifer fill materials shall be clean (relatively free of clays and organic materials) before placement in the well. Disinfection shall be accomplished by dissolving sufficient chlorine compound to produce a calculated concentration of at least 100 ppm available chlorine in double the volume of water

[illegible]

[illegible]

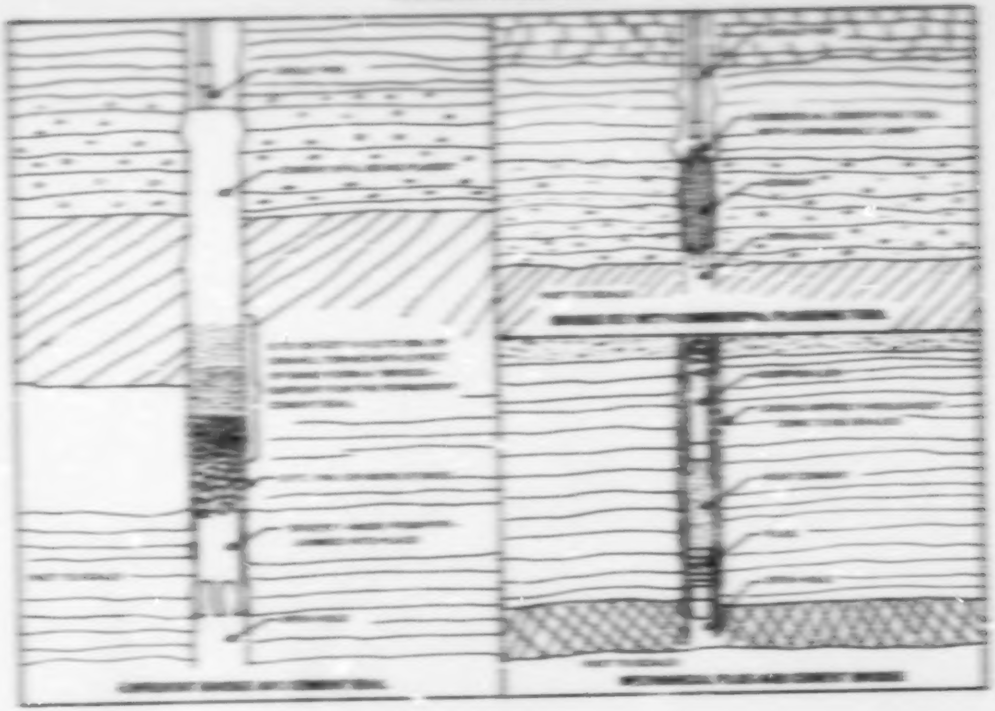
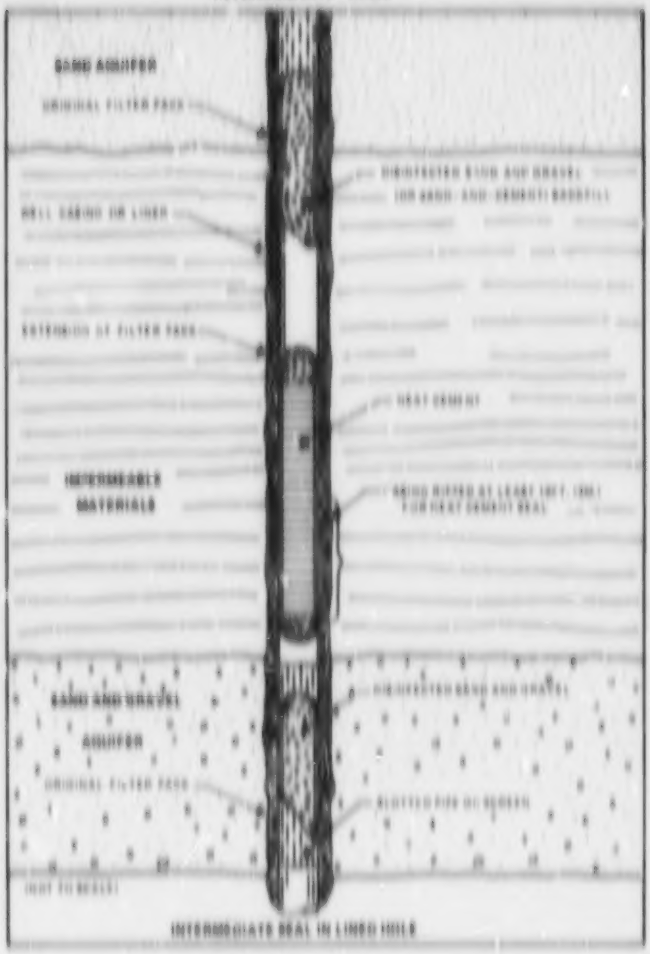
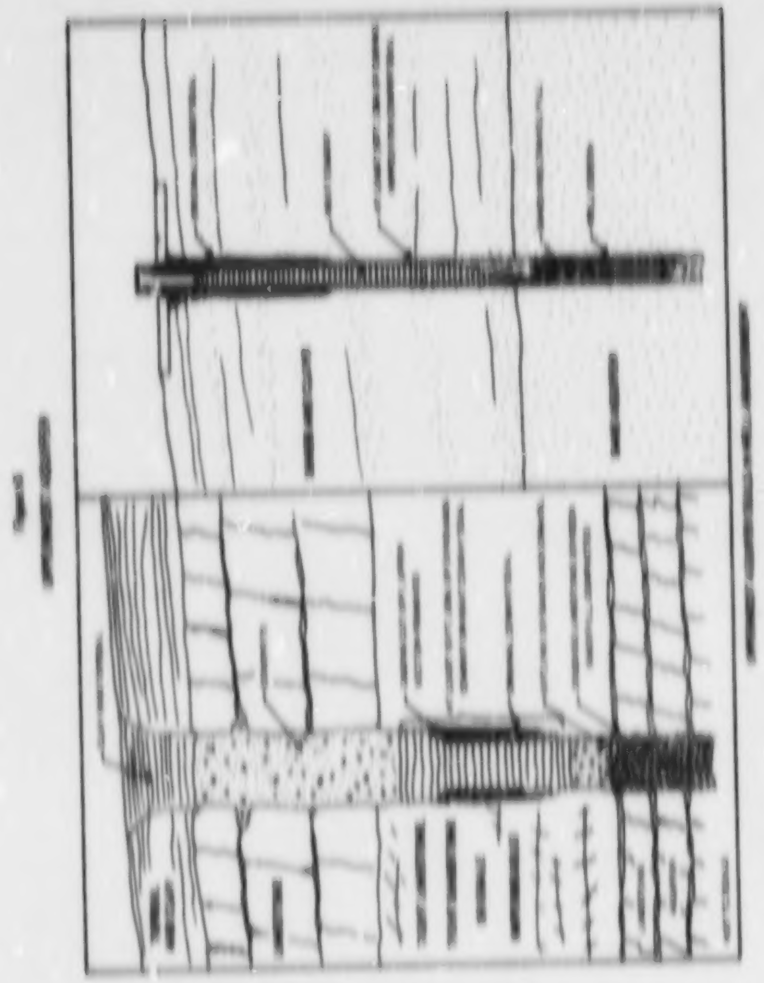


Figure 5
INTERMEDIATE SEALS


SAND AQUIFER
ORIGINAL FILTER PACK
DISINFECTED SAND AND GRAVEL
(OR SAND- AND- CEMENT) BACKFILL
WELL CASING OR LINER
EXTENSION OF FILTER PACK
NEAT CEMENT
IMPERMEABLE
MATERIALS
CASING RIPPED AT LEAST 10 FT. (3M)
FOR NEAT CEMENT SEAL
SAND AND GRAVEL
AQUIFER
DISINFECTED SAND AND GRAVEL
ORIGINAL FILTER PACK
SLOTTED PIPE OR SCREEN
(NOT TO SCALE)
INTERMEDIATE SEAL IN LINED HOLE



in the well. The fill material shall be placed in the well after the water in the well has been so treated.

PERMANENT BRIDGES

56.010-000-000. ***Permanent Bridges.*** Permanent bridges may be used to avoid having to fill very deep holes below the deepest point at which a permanent seal is required. Permanent bridges shall be composed only of cement or cement-bearing minerals. The cement shall be allowed to harden for at least 24 hours, if Type I cement is used, or for at least 12 hours if Type III (high early strength) cement is used, before backfilling is continued. Temporary bridges used to provide a base for the permanent bridge shall consist only of inorganic materials—except that patented devices containing expandable neoprene, plastic, and other elastomers, and specifically designed for use in well construction are acceptable.

PLACEMENT OF GROUT

56.001-000-000. ***Placement Operations.*** Concrete, sand-and-cement grout, or cement grout used as a sealing material in abandonment operations shall be introduced at the bottom of the well or interval to be sealed (or filled) and placed progressively upward to the top of the well. All such sealing materials shall be placed by the use of grout pipe, tremie, cement bucket or dump bailer, in such a way as to avoid segregation or dilution of the sealing materials. Dumping grout material from the top shall not be permitted.

Seals intended to prevent vertical movement of water in the well or bore hole shall be composed of cement, sand-and-cement, or concrete—except that where such seals must be placed within casing or liners, only neat cement grout may be used. The cement-water ratio shall be that specified in Article 48.100-000-000. Cement seals shall be placed by means of pumping through drop pipe or by use of a dump-bailer, with placement beginning at the bottom and continuing upward. The minimum cement seal length, wherever dimensions permit, shall be 10 feet.

56.002-000-000. ***Intermediate Seals.*** Intermediate seals of cement, sand-and-cement, or concrete shall be placed in impermeable strata between aquifers which are identifiable as, or are suspected of being, hydraulically separated under natural, undisturbed conditions. Once the required cement seal has been installed, the remainder of the impermeable zone or non-producing zone between aquifers shall be filled with sand, sand and gravel, or cement-bearing mineral material.

56.003-000-000. ***Seal at Uppermost Aquifer.*** A cement, sand-and cement, or concrete seal shall be installed in the least permeable zone immediately above the uppermost water-producing zone. Such seals shall be placed only in quiescent (non-flowing) water. (See Preamble (56) for instructions on how to seal flowing wells.

56.004-000-000. ***Seals Placed Within Casing, Liners, Filters, etc.*** Seal which must be placed in casing, liners, or filters require special attention. The material between the well and the face of the bore hole shall be thoroughly perforated, ripped, or otherwise disintegrated as the necessary first step. Neat cement only, or neat cement with a maximum of 5 percent by weight of commercially processed bentonite clay, shall be used as the seal. Either of two methods may be used.

1. The calculated amount of grout required to fill the well interval plus the annular space outside the lining shall be placed within the space to be cemented, running the cement through a special cementing packer manufactured for this purpose and installed immediately above the perforated or ripped zone. The cement shall be injected at a pressure calculated to be at least 50 psi greater than the normal hydrostatic pressure within the well at the point of injection.
2. The calculated amount of cement grout required to fill the casing interval plus the annular space outside the lining, plus sufficient cement grout to fill an additional 10 feet of the lining, shall be introduced at the bottom of the interval to be cemented.

PLACEMENT OF FILL

56.000-100-000. ***Non-Producing Zones.*** Non-producing zones above the aquifer shall be filled with stable materials such as sand, sand-and-gravel, cement, cement-and-sand, or concrete. Non-producing zones above the uppermost aquifer seal shall be filled with materials less permeable than the surrounding undisturbed formations. The uppermost 5 feet of the bore hole (at land surface) shall be filled with a material appropriate to the intended use of the land.

SPECIAL CONDITIONS

56.000-010-000. ***Pre-existing Contamination.*** An abandoned well which has already been affected by salt water intrusion or any other contaminants shall be considered a special case, and the method of filling and sealing such wells shall be subject to individual review and written approval by the regulatory agency involved.

In the sealing of a double or multiple cased well, the CONTRACTOR shall submit a drawing thereof with a description of the proposed procedure and materials to be used, for prior approval by the regulatory agency involved.

Mineral exploration holes, solution or "in situ" mining wells, dewatering wells, temporary service wells, construction water wells, process wells, and/or other structures which affect the withdrawal or quality of ground water, or the elevation of the water table, regardless of location or intended length of life of the structure, shall be abandoned according to standards and minimums as described herein for water supply wells.

WELL ABANDONMENT RECORDS

56.000-001-000. ***Recording Location of Abandoned Well or Bore Hole.*** Before equipment is removed from the site, the exact location of the abandoned well or hole shall be determined and recorded, "tying in" the location with permanent reference points, or as prescribed by the state or local regulatory agency. All information relative to the abandonment procedure and the location of the abandoned well shall be prepared and assembled as prescribed by the state or local regulatory agency, with copies supplied to the respective agency and the owner of the land.

METHOD OF PAYMENT FOR ABANDONMENT

56.000-000-100. ***Method of Payment.***

Option A (Lump Sum): All of the work performed under this Article (56) shall be paid for as a lump sum.

Option B (Time and Materials): All of the work performed under this Article (56) shall be paid for on the basis of the price bid for well construction equipment per hour plus materials at cost plus percent of add-on bid.

Option C (Unit Price): All of the following work performed under this Article (56) shall be paid for at the unit price bid per hour for well construction equipment plus the cost of any materials and/or subcontracted services at the invoice price plus percent of add-on bid:

Well Abandonment ....Unit Price/Foot

Appendix A

Sample Notice to Bidders

1. Sealed bid, addressed to ________________________________,
(Agency)
will be received at the ________________ office at ________________
(Address)
________________ until ________________________, and then publicly
(time) (date)
opened and read for furnishing all plant, labor material and equipment and performing all work required for the construction of:

for ________________, ________________, ________________
(Name) (County) (State)
hereinafter called Owner.

2. Bids shall be submitted in sealed envelopes upon the blank form of proposal furnished. Sealed envelopes shall be marked in the upper left hand corner as follows:

Sealed Bid
Bid for ________________
____
To be Opened ________________
(Time)
____
(Date)

3. All proposals shall be accompanied by a cashier's or certified check or bid bond upon a national or state bank or surety company in the amount ________% of the total amount for the base bid payable to ________________________________, as a guarantee that the
(Owner)
bidder will enter into a contract and execute performance bond within ________________ (____) days after notice of award and that his bid will
(No.)
not be withdrawn within ________________________ (____) days
(No.)
after the date of opening of bids without the consent of the Owner. Bids without check will not be considered.

4. All bid securities will be returned to the respective bidders within ________________ (____) days after bids are opened, except those which
(No.)
the Owner elects to hold until the successful bidder has executed the contract and furnished the required bonds. Thereafter all remaining securities,

including security of the successful bidder, will be returned within ________
(No.)

(____) days.

5. The successful bidder must furnish both a performance bond and a payment bond upon approved standard form in the amount of ________% of the contract price from an approved surety company licensed by the state of ____________________, or acceptable, according to the latest list of companies holding certificates of authority from the Secretary of the Treasury of the United States, or other surety or sureties acceptable to the Owner.

6. The right is reserved, as the interest of the Owner may require to reject any and all bids, and to waive any informality in bids received.

7. Prospective bidders and suppliers may obtain specifications and bidding documents from the office of ____________________
(Agency)

on deposit of: ____________________
(Price)

per set, which sum so deposited will be refunded to bidders provided all documents are returned in good condition to the office from which they were issued, not later than ________ (____) days after the time bids
(No.)

are received. Drawings and specifications may be examined at the ________

____
(Location)

8. Bidders should carefully examine the plans, specifications and other documents, visit the site of the work, and fully inform themselves as to all conditions and matters which can in any way affect the work or the cost thereof. Should a bidder find discrepancies in, or omission from the plans, specifications, or other documents, or should he be in doubt as to their meaning, he should at once notify the Owner and obtain clarification prior to submitting any bid.

9. Addenda to the specifications and revised drawings issued to bidders prior to the receipt of bids shall be considered part of the contract documents. Bidders shall acknowledge receipt of addenda and revised drawings on the proposal form.

Appendix B

Sample Proposal

For furnishing all Plant, Labor, Equipment and Materials and Performing all Operations necessary for the construction of

________________________ in ________________________
(Project) (Location)

____
(Address of Owner or Owner's Representative)

____
____
____
____
____

Gentlemen:

The undersigned, as Bidder, declares that he has carefully examined the Notice to Bidders, Specifications, and the drawings herein referred to for $________________________ for the ________________________
(Project) (Agency)
and has carefully examined the locations, conditions, and classes of material of the proposed work, and agrees that he will provide all the necessary machinery, apparatus, tools, and other means of construction, and will do all the work and furnish all materials called for in the contract and specifications in the manner prescribed therein and according to the requirements of the engineer as therein set forth for the amount below.

____
(Description of Project)

Item No.	Qty	Unit	Description of item with unit bid price written in words	Total amount bid

It is understood and agreed that the work shall be completed in full within ________ calendar days after the date on which work is to be commenced as established by the Contract Documents.

Accompanying this proposal is a certified check, cashier's check or bid bond, in the amount of $________________________
made payable to ________________________
(Owner)

It is understood that the bid security accompanying this proposal shall be returned to the undersigned unless, in case of the acceptance of this proposal, the undersigned should fail to enter into a construction contract and execute bonds as required it is understood and agreed that the bid security shall be forfeited to the Owner and shall be considered as payment for damages due to delay and other inconveniences suffered by the Owner as a result of such failure on the part of the undersigned.

It is understood that the Owner reserves the right to reject any and all bids.

In the event of Award of the Contract to the undersigned, the undersigned agrees to furnish Performance and Payment Bonds, as provided in the Specifications.

The undersigned certifies that the bid prices contained in this proposal have been carefully checked and are submitted as correct and final.

Date__________________ Signed______________________________
(Company)
By______________________________
(Title)
____
(Address)

Witness______________________________
Seal (If Bidder is a Corporation)
Acknowledge Receipt of Addenda Below:
Addendum No. __________ __________ __________ __________
Date Received __________ __________ __________ __________

Appendix C

Unit Price Proposal

TO

____

FOR

____

____

Submitted by:

____

____

UNIT PRICE PROPOSAL

The undersigned acknowledges receipt of Drawings and Specifications as listed under "Instruction to Bidders" dated ______________________

____

____

____

____

The undersigned agrees to furnish all labor, materials and facilities required for the execution of all the work called for in these Drawings and Specifications for the unit prices set forth in the schedule of unit priced appended hereto as Addendum A.

It is understood and agreed that the number of units of each item as taken off the Drawings and set forth in Addendum A by the Bidder is approximate and that payment will be made for the actual number of such units incorporated in the work.

The undersigned, if he is the successful bidder, agrees to execute an agreement with the Owner incorporating this Proposal and the various Contract Documents. Failure to execute such an agreement, however, shall not release the undersigned for a period of thirty days after termination of bidding from any or all obligations incurred by the submission of this Proposal and its acceptance by the Owner.

BULLETINS: The undersigned further acknowledges receipt of Bulletins as listed herewith and represents that any additions or modifications to or deletions from the work called for in those Bulletins are included in this Proposal.

Bulletin number   Dated

(*Note:* If no Bulletins have been received write in "none".)

SUBCONTRACTORS: If awarded a contract for work proposed herein and subsequent thereto the undersigned agrees to submit within thirty days to the Owner for approval a list of those subcontractors he proposes to employ in the execution of this contract work; and that he will let no subcontracts nor authorize any proposed subcontractor to start work or resume obligations for equipment and/or materials until receipt of written approval from the Owner; and that upon written request by the Owner will supply experience histories, financial data and such other qualifying information required by the owner to fairly and completely evaluate the proposed subcontractor's qualifications; and that subsequent to letting subcontracts will provide the Owner with a breakdown of various subcontract amounts which will be used in processing partial payments.

SUBDIVISIONS OF THE PROPOSED AMOUNT: The undersigned agrees, if awarded the Contract, that all invoices pertinent to the work will be broken down in accordance with the Owner's major accounting subdivisions as listed in the Schedule of Account Numbers in the "Instructions to Bidders."

FEES FOR ADDITIONAL WORK: The undersigned agrees that his fee for additional work performed by direction of the Owner and not covered by unit prices set forth in this Proposal will be as follows:

For work of Subcontractors ______________________%

For work of Contractor's own forces ________________%

The cost of such additional work shall be determined as outlined in the General Conditions, as pertains to Change Orders and Field Orders.

FEES FOR ASSUMING CONTRACTS: The undersigned agrees to assume and administer as subcontracts such other contracts for related work as the Owner may elect to assign. The undersigned further agrees to accept a fee of ______________% of the assigned contract amount or amounts, which fee shall be payment in full for assuming such contracts and administering them as subcontracts.

TIME OF COMPLETION: The undersigned agrees to start the work immediately upon receipt of notice of award of contract and to carry the work continuously to completion. The undersigned does hereby declare the number of consecutive calendar days he will require to complete the work to be ________________ based on a forty-hour work week. The succesful bidder will be required, within thirty days, to file with the Owner, in duplicate, fully executed job schedules providing for completion within the time so declared.

TAXES: All Federal, State and Local Taxes of all types, including but not limited to any Excise Taxes, taxes upon personal property and Sales and Use Taxes, when applicable, shall be included in the Proposal amount, and whenever required by law shall be separately stated.

BONDS: If required, the undersigned will furnish performance and payment bonds, the bond premium to be charged for separately and additionally to the bid price. The undersigned represents that this Proposal does not include any amount for the cost of such bonds.

ASSIGNMENT: The undersigned represents that no assignment, sublease, or transfer of all or any part of his interest in this proposal has been made or will be made prior to the Owner's acceptance hereof, and the undersigned agrees thereafter not to assign, sublet or transfer all or any part of his interest herein without the written consent of the Owner.

ADDRESS, LEGAL STATUS AND SIGNATURE OF BIDDER: The undersigned Bidder does hereby designate the address give below as the legal address to which all notices, directions, or other communications may be served, or mailed.

Street Address ____

City ____________________________ State ____________________

The undersigned does hereby declare that the Bidder has the legal status checked below:

____________ Individual

____________ Co-Partnership

____________ Corporation, incorporated under the laws of the State of

____

____

____________ Doing business under an assumed name.

Appendix D

Bid Schedule

Bid item	Method of payment article	Description	Estimated quantity	Units	Unit price	Total price
	45.	*Test Holes and Samples*				
1.		a. ______" Diameter	______	Lin. ft.	$______	$______
2.		a. ______" Diameter	______	Lin.ft.	______	______
3.		b. Geophysical/Mechanical Logs: (Type) ______	______	Lin.ft.	______	______
4.		c. Stratigraphic Logs	______	Each	______	______
5.		d. Formation Samples	______	Each	______	______
6.		e. Water (Aquifer) Samples	______	Each	______	______
7.		f. Services of Log Analyst	______	Each	______	______
	46.	*Well Construction*				
8.		a. ______" Diameter	______	Lin. ft.	$______	$______
9.		a. ______" Diameter	______	Lin.ft.	______	______
10.		b. Geophysical/Mechanical Logs: (Type) ______	______	Lin.ft.	______	______
11.		c. Formation Samples	______	Each	______	______
12.		d. Services of Log Analyst	______	Each	______	______
	47.	*Well Casing Installation*				
13.		a. ______" Diameter	______	Lin. ft.	$______	$______
14.		a. ______" Diameter	______	Lin.ft.	______	______
15.		b. Pitless Unit	______	Each	______	______
16.		c. Pressure Testing	______	Each	______	______
	48.	*Well Grouting Installation*				
17.		a. Grouting Installation	______	Each/bag	$______	$______
18.		b. Cement Bond Log	______	Lin.ft.	______	______
19.		c. Pumping Grout Services	______	Cu. yd.	______	______
20.		d. Pressure Testing	______	Each	______	______
	49.	*Well Screens and Perforations*				
21.		a. Screen or Perforated Casing Furnished and Installed	______	Lin. ft.	$______	$______
	50.	*Well Filter Construction (Artificial)*				
22.		a. Artificial Well Filter Furnished and Installed	______	Lin. ft.	$______	$______
23.		b. Filter Material	______	Cu. yd.	______	______
	51.	*Well Plumbness and Alignment*				
24.		a. Plumbness and Alignment Tests	______	Each	$______	$______
25.		b. Drift Indicator Tests	______	Each	______	______

Bid Item	Method of payment Article	Description	Estimated quantity	Units	Unit price	Total price
	52	*Well Development*				
86		a. Well Development	____	Each/ hr.	$____	$____
87		b. Chemicals	____	Each/ bag	____	____
	53	*Well Testing for Performance*				
88		a. Installation and Removal of Testing Equipment	____	Each	$____	$____
89		b. Recovery Stand-by Time	____	Per hr.	____	____
90		c. Discharge Pipe	____	Lin.ft.	____	____
	54	*Well Disinfection*				
91		a. Well Disinfection	____	Per hr.	$____	$____
92		b. Chemicals	____	Per bag	____	____
	55	*Water Samples and Analyses*				
93		a. Water Analyses	____	Per Series	$____	$____
	56	*Permanent and Test Hole Well Abandonment, and Temporary Capping*				
94		a. Well Abandonment	____	Lin. ft.	$____	$____
95		b. Temporary Capping	____	Each	____	____

The names and addresses of all persons interested as principals in this Proposal are as follows:

Name	Address
____	____
____	____
____	____
____	____

Signature of Bidder

Name____

By____

Date____

Standard Form of Agreement Between Owner and Contractor

THIS AGREEMENT made as of the ____________ day of ____________
____________ in the year 19____ by and between,
____________ (hereinafter called the **OWNER**) and
____________ (hereinafter called the **CONTRACTOR**)

WITNESSETH THAT the **OWNER** and **CONTRACTOR** in consideration of the mutual covenants hereinafter set forth, agree as follows:

Article 1. **WORK.** The **CONTRACTOR** will perform all Work as shown in the Contract Documents for the completion of the Project generally described as follows: Construction of ____________
____
____
____
____

Article 2. **ENGINEER.** The Project has been designed by ____________
____
____

[illegible]

Article 3. **CONTRACT TIME.** The Work shall be completed within ________ calendar days after the date which the **OWNER** shall designate in writing to the **CONTRACTOR** as the date on which it is expected that the **CONTRACTOR** will start the Work.

Article 4. **CONTRACT PRICE.** The **OWNER** will pay the **CONTRACTOR** for performance of the Work and completion of the Project in accordance with the Contract Documents subject to adjustment by Modifications as provided therein as follows:

Article 5. **PROGRESS AND FINAL PAYMENTS.** The **OWNER** will make progress payments on account of the Contract Price as provided in the General Conditions as follows:

5.1 Progress and final payments will be on the basis of the **CONTRACTOR**'s Applications for Payment as approved by the **OWNER**.

5.2 On or about the ____th day of each month during construction: ________ percent of the Work completed and, ________ percent of material and equipment not incorporated in the Work but delivered and suitably stored, less in each case the aggregate of payments previously made.

5.3 Upon Substantial Completion, a sum sufficient to increase the total payments to the CONTRACTOR to ______ percent of the Contract Price less retainages as the OWNER shall determine for all incompleted work and unsettled claims.

5.4 Upon final completion of the Work and Settlement of all claims, the remainder of the Contract Price.

Article 6. CONTRACT DOCUMENTS. The Contract Documents which comprise the contract between the OWNER AND THE CONTRACTOR are attached hereto and made a part hereof and consist of the following:

6.1 This Agreement (Pages ____ to ____ inclusive),

6.2 Exhibits to this Agreement (Pages ____ to ____ inclusive)

6.3 Specifications consisting of:

Notice to Bidders	(Pages ____ to ____ inclusive)
General Conditions	(Pages ____ to ____ inclusive)
Special Conditions	(Pages ____ to ____ inclusive)
Technical Provisions	(Pages ____ to ____ inclusive)

6.4 Drawings and Plans as listed in the attached Exhibit ________

6.5 Addenda numbers (to inclusive), and

6.6 Any Modifications, including Change Orders, duly delivered after execution of this Agreement.

Article 7. MISCELLANEOUS

7.1 Terms used in this Agreement which are defined in Article 1 of the General Conditions shall have the meanings indicated in the General Conditions.

7.2 Neither the OWNER nor the CONTRACTOR shall, without the prior written consent of the other, assign or sublet in whole or in part his interest under any of the Contract Documents and, specifically, the CONTRACTOR shall not assign any monies due or to become due without the prior written consent of the OWNER.

7.3 The OWNER and the CONTRACTOR each binds himself, his partners, successors, assigns and legal representatives to the other party hereto in respect of all covenants, agreements and obligations contained in the Contract Documents.

7.4 The Contractor Documents constitute the entire agreement between the OWNER and the CONTRACTOR and may only be altered, amended or repealed by a duly executed written instrument.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement the day and year first above written.

OWNER________________________ CONTRACTOR________________________
By___________________________ By___________________________
(CORPORATE SEAL) (CORPORATE SEAL)
Attest:_______________________ Attest:_______________________

APPENDIX [illegible]

National Water Well Association

STANDARD FORM

WELL ESTIMATE AND/OR WELL DRILLING CONTRACT OR REPAIR ORDER AGREEMENT

Purchaser's Name ______________________ Date ______________

Address ______________________________________

City ______________________ State ______________________

WELL PERMIT COST $ ____________

1. WELL AND PRICE ______________________________________

____

____

2. PUMP AND PRICE ______________________ $ ____________

3. SCREEN AND PRICE ______________________ $ ____________

4. DEVELOPMENT, SURGING AND PRICE ______________________ $ ____________

5. CHLORINATION AND PRICE ______________________ $ ____________

6. REPAIR WORK AND PRICE ______________________ $ ____________

7. TOTAL CASH PRICE ______________________ $ ____________

8. TOTAL DOWN PAYMENT ______________________ $ ____________

9. AMOUNT FINANCED ______________________ $ ____________

10. FINANCE CHARGE ______________________ $ ____________

11. TOTAL OF PAYMENTS ______________________ $ ____________

12. DEFERRED PAYMENT PRICE (7 + 10) ______________________ $ ____________

13. ANNUAL PERCENTAGE RATE ______________________ %

14. [illegible]

15. The depth of the well shall be measured from the top of the ground to the bottom of the well and it is agreed that if the depth be [illegible]

16. Drilling Contractor reserves the right to reduce the size of the casing and/or abandon drilling. If drilling is abandoned [illegible]

17. All electric wiring, installations and connections, and any and all non-drilling work, will be furnished by the Purchaser [illegible]

18. LEGAL DESCRIPTION ________ of Section ________ Twp ________ Range or Lot ________ in Block ________ Plat ________ in the City of ________ State ________ [illegible]

19. The undersigned agrees that title to and to any and all materials furnished by the Drilling Contractor [illegible]

20. Interest at the rate of [illegible] per cent will be charged on all money not paid when due.

21. All agreements and understandings are contained herein and there are no verbal representations or agreements not herein contained.

22. I hereby authorize the above contract [illegible]

23. BANK REFERENCES ____________________

THIS CONTRACT ACCEPTED BY PURCHASER	DRILLING CONTRACTOR
____________________	____________________
Address ____________________	Address ____________________
Telephone No. ____________	Telephone No. ____________

[illegible]

Signature ____________________

[illegible]

NOTICE TO PURCHASER: [illegible]

[illegible]

NOTICE OF RESCISSION

____________________ Owner's Name

____________________ Date

____________________ Owner's Name

____________________ Address

____________________ Contractor's Name

____________________ (Identification of Transaction)

Notice to Customer Required By Federal Law

You have entered into a transaction on ____________________ (Date)

[illegible]

____________________ (Name of Creditor)

at ____________________ (Address of Creditor's Place of Business)

by mail or telegram sent not later than midnight of ____________________ (Date)

[illegible]

I hereby cancel this transaction

____________________ (Date)

____________________ (Customer's Signature)

Note: Each owner of property on which well is to be drilled [illegible] receive a copy of this form.

Appendix D

METRIC-ENGLISH UNIT CONVERSION TABLE

(Read as follows: Dimension: 1 metric unit (symbol) equals English equivalent)

Length:
1 meter (m) = 39.37 inches = 3.28 feet = 1.09 yards
1 kilometer (km) = 0.62 miles
1 millimeter (mm) = 0.03937 inches
1 centimeter (cm) = 0.3937 inches
1 micrometer (µm) = 3.937×10^{-5} = 10^{4} Å

Area:
1 square meter (m^2) = 10.764 square feet = 1.196 square yards
1 square kilometer (km^2) = .386 square miles = 247 acres
1 square centimeter (cm^2) = 0.155 square inches
1 square millimeter (mm^2) = 0.00155 square inches
1 hectare (ha) = 2.471 acres

Volume:
1 cubic meter (m^3) = 35.314 cubic feet = 1.3079 cubic yards
1 cubic centimeter (cm^3) = 0.061 cubic inches
1 liter (l) = 1.057 quarts = 0.264 gallons = 8.11×10^{-4} acre-feet

Mass:
1 kilogram (kg) = 2.205 pounds
1 gram (g) = 0.0353 ounces = 15.43 grains
1 milligram (mg) = 0.01543 grains
1 tonne (t) = 0.984 ton (long) = 1.1023 ton (short)

Time:
second day (s d [illegible])   year (a) [illegible]

Force:
1 newton (N) = 0.22481 pounds (weight) = 7.2 poundals

Velocity, linear:
1 meter per second (m/s) = 3.28 feet per second
1 millimeter per second (mm/s) = 0.00328 feet per second
1 kilometers per second (km/s) = 2.230 miles per hour

Velocity, angular:
radians per second (rad/s)

Flow (volumetric):
1 cubic meter per second (m^3/s) = 15.850 gallons per minute = 2.120 cubic feet per minute
1 liter per second (l/s) = 15.85 gallons per minute

Viscosity:
poise = 2.09×10^{-3} pounds (weight) seconds/square foot

Pressure:
1 newton per square meter (N/m^2) = 0.00015 pounds per square inch
1 kilonewton per square meter (kN/m^2) = 0.145 pounds per square inch
1 kilogram (force) per square centimeter = 14.223 pounds per square inch

Temperature:
1 degree Kelvin (K) or 1 degree Celsius (C) = $\frac{9}{5}$ [illegible]

Work, energy, quantity of heat:
1 joule (J) = 2.778×10^{-7} kilowatt-hours = 3.725×10^{-7} horsepower-hours = 0.7376 foot-pounds = 9.48×10^{-4} British thermal units
1 kilojoule (kJ) = 2.778 kilowatt-hours

Power:
watt (W)   kilowatt (kW)
joule per second (J/s)

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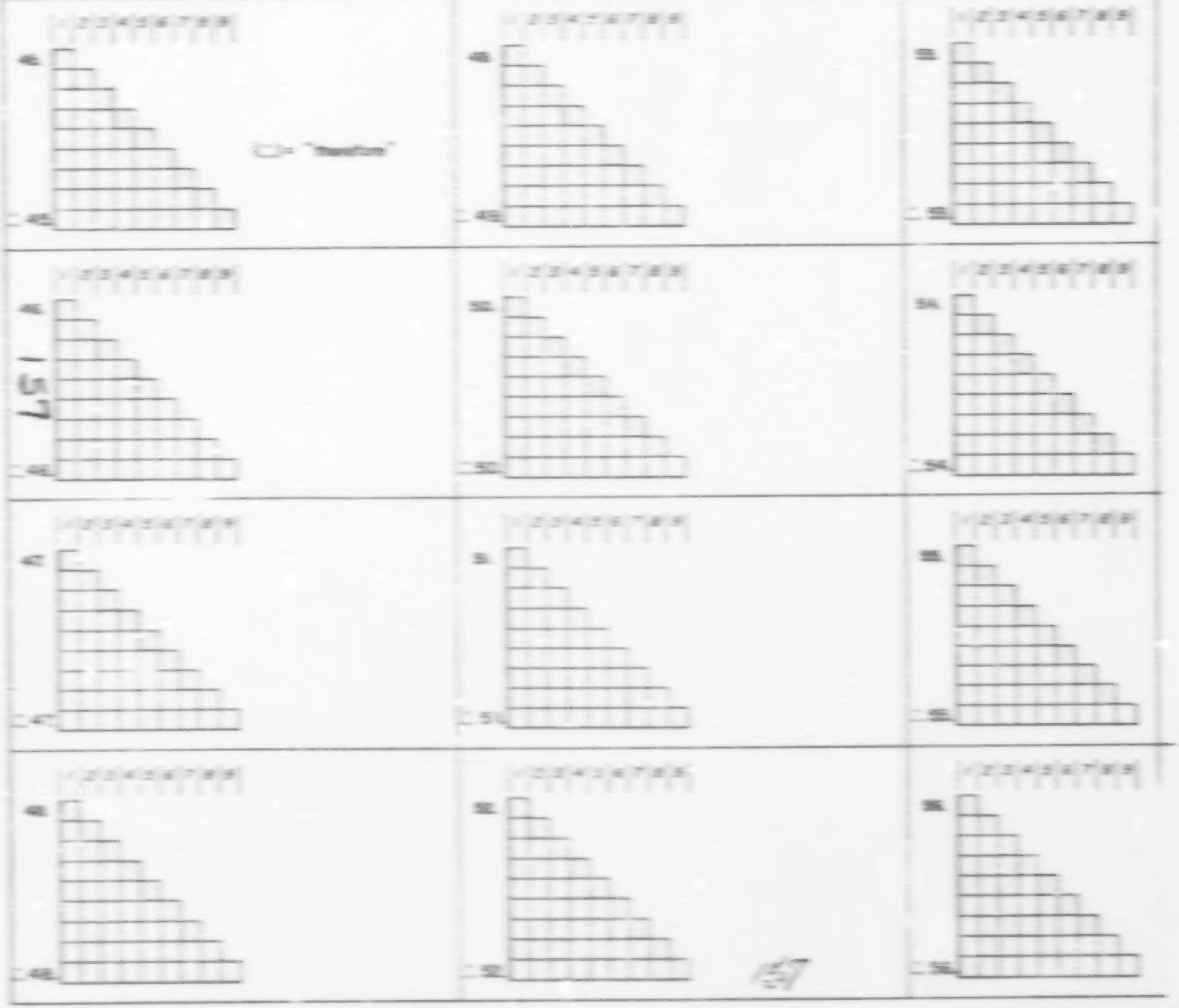
SPECIFICATIONS PREPARATION WORKSHEET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SPECIFICATIONS PREPARATION WORKSHEET GUIDE*

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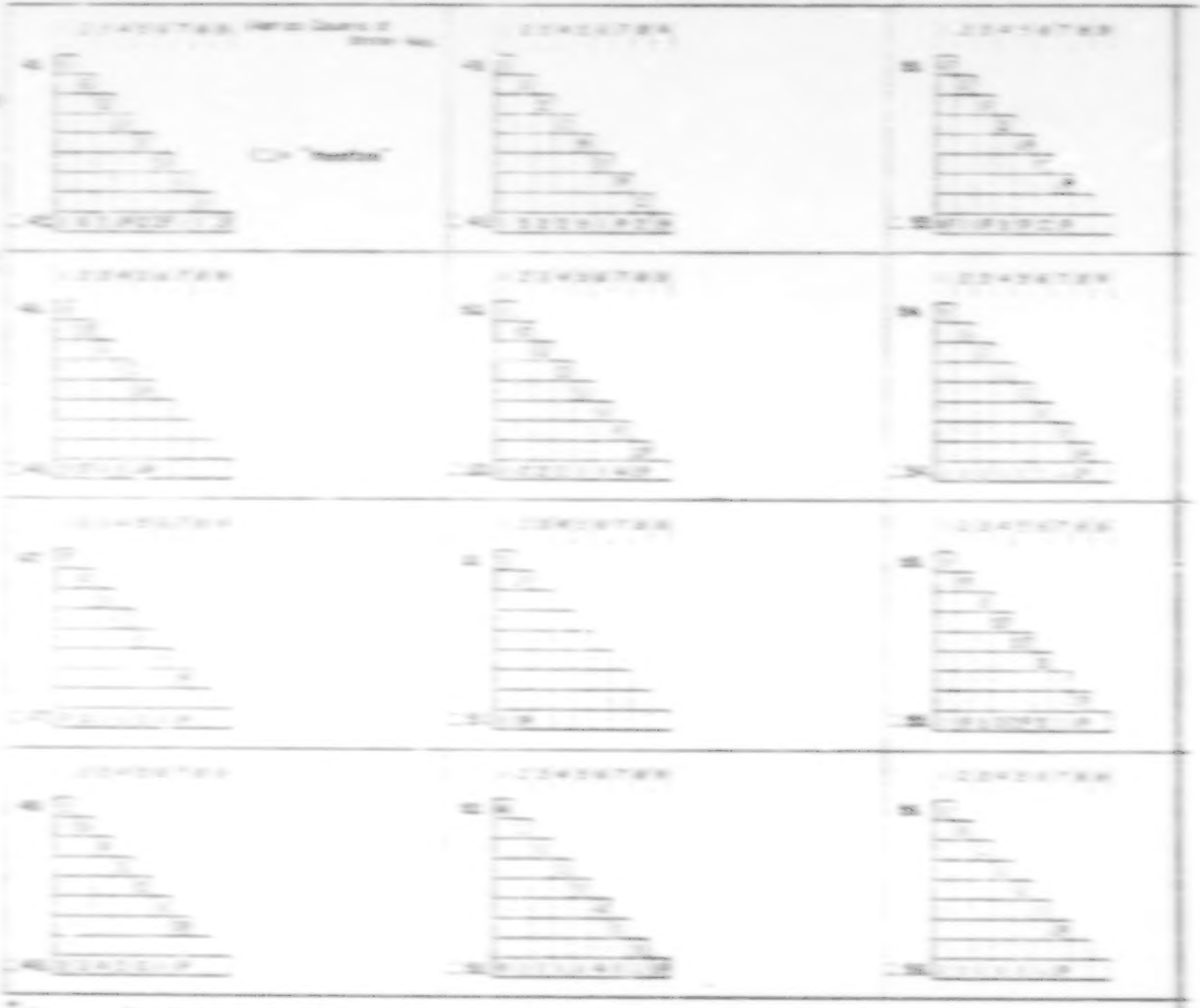

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* See [illegible] Worksheet for Preparation of Your Own Specifications.

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